PB86-126448

Second Review of New Source Performance Standards for Asphalt Concrete Plants

(U.S.) Environmental Protection Agency
Research Triangle Park, NC

Oct 85

U.S. Department of Commerce
National Technical Information Service
NTIS

PB86-126448

United States
Environmental Protection
Agency

Office of Air Quality
Planning and Standards
Research Triangle Park NC 27711

EPA-450/3-85-024
October 1985

Air

EPA

Second Review Of New Source Performance Standards For Asphalt Concrete Plants

NSPS

REPRODUCED BY
NATIONAL TECHNICAL
INFORMATION SERVICE
U.S. DEPARTMENT OF COMMERCE
SPRINGFIELD, VA. 22161

TECHNICAL REPORT DATA
(Please read Instructions on the reverse before completing)

1. REPORT NO. EPA 450/3-85-024	2.	3. RECIPIENT'S ACCESSION NO. PB86 126448 /AS
4. TITLE AND SUBTITLE Second Review of New Source Performance Standards for Asphalt Concrete Plants		5. REPORT DATE October 1985
		6. PERFORMING ORGANIZATION CODE
7. AUTHOR(S)		8. PERFORMING ORGANIZATION REPORT NO.
9. PERFORMING ORGANIZATION NAME AND ADDRESS Office of Air Quality Planning and Standards U.S. Environmental Protection Agency Research Triangle Park, NC 27711		10. PROGRAM ELEMENT NO.
		11. CONTRACT/GRANT NO.
12. SPONSORING AGENCY NAME AND ADDRESS DAA for Air Quality Planning and Standards Office of Air and Radiation U.S. Environmental Protection Agency Research Triangle Park, NC 27711		13. TYPE OF REPORT AND PERIOD COVERED
		14. SPONSORING AGENCY CODE EPA 200/04
15. SUPPLEMENTARY NOTES		

16. ABSTRACT

This report reviews the current New Source Performance Standards for Asphalt Concrete Plants. It includes a summary of the current standards, the status of current applicable control technology, and the ability of plants to meet the current standards.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
Air Pollution Asphalt Concrete Plants Hot Mix Asphalt Facilities Particulate Matter Standards of Performance Pollution Control	Air Pollution	13B

18. DISTRIBUTION STATEMENT Unlimited	19. SECURITY CLASS *(This Report)* Unclassified	21. NO. OF PAGES 146
	20. SECURITY CLASS *(This page)* Unclassified	22. PRICE

EPA Form 2220-1 (Rev. 4-77) PREVIOUS EDITION IS OBSOLETE

EPA-450/385-024

Second Review of New Source Performance Standards for Asphalt Concrete Plants

Emissions Standards and Engineering Division

U.S. ENVIRONMENTAL PROTECTION AGENCY
Office of Air and Radiation
Office of Air Quality Planning and Standards
Research Triangle Park, North Carolina 27711
October 1985

i-a

This report has been reviewed by the Emission Standards and Engineering Division of the Office of Air Quality Planning and Standards, EPA, and approved for publication. Mention of trade names or commercial products is not intended to constitute endorsement or recommendation for use. Copies of this report are available through the Library Services Office (MD-35), U.S. Environmental Protection Agency, Research Triangle Park, North Carolina 27711; or, for a fee, from the National Technical Information Services, 5285 Port Royal Road, Springfield Virginia 22161.

TERMINOLOGY SHEET

Since the development of this review document, the National Asphalt Paving Association (NAPA) has suggested that terminology used in the asphalt concrete industry be standardized. The association suggests using the terms "hot mix asphalt (HMA)" instead of "asphalt concrete"; "HMA facility" instead of "asphalt concrete plant"; "virgin hot mix asphalt" or "virgin HMA" instead of "conventional mix"; and "recycled hot mix asphalt" or "recycled HMA" instead of "recycled asphalt pavement (RAP)." Subsequent documents should use the terminology suggested by NAPA.

TABLE OF CONTENTS

Page

LIST OF FIGURES viii

LIST OF TABLES ix

CHAPTER 1. EXECUTIVE SUMMARY 1-1

1.1 Regulatory History of Current Standard 1-1
1.2 Industry Trends 1-2
1.3 Control Technology 1-2
1.4 Compliance Test Data 1-3
1.5 Cost Considerations Affecting the NSPS 1-3
1.6 Enforcement Aspects 1-4

CHAPTER 2. THE ASPHALT CONCRETE INDUSTRY 2-1

2.1 Industry Characterization 2-1
  2.1.1 Description of Industry 2-1
  2.1.2 Asphalt Concrete Facilities Subject to NSPS 2-3
  2.1.3 Industry Growth Projections 2-3
2.2 Raw Materials 2-5
  2.2.1 Aggregate 2-5
  2.2.2 Asphalt Cement 2-5
  2.2.3 Recycled Asphalt Pavement 2-6
  2.2.4 Rejuvenating Agents 2-6
  2.2.5 Sulfur 2-8
2.3 Operations of Asphalt Concrete Plants 2-8
  2.3.1 Batch Plants 2-8
  2.3.2 Continuous-Mix Plants 2-13
  2.3.3 Drum-Mix Plants 2-13
  2.3.4 Indirect Heated Plant 2-16
  2.3.5 Coal as Fuel 2-19
2.4 Emissions 2-19
  2.4.1 Air Emissions 2-19
    2.4.1.1 Batch Plants 2-19
    2.4.1.2 Continuous Mix Plants 2-20
    2.4.1.3 Drum-Mix Plants 2-20
  2.4.2 Effect of Asphalt Cement Grade on Emissions 2-20
2.5 References for Chapter 2 2-21

CHAPTER 3. CURRENT STANDARDS FOR FOR ASPHALT CONCRETE PLANTS 3-1

3.1 Facilities Affected 3-1
3.2 Controlled Pollutants and Emission Levels 3-2

Preceding page blank

TABLE OF CONTENTS (continued)

Page

3.3 Testing and Monitoring Requirements............. 3-2
  3.3.1 Testing Requirements..................... 3-2
    3.3.1.1 Particulate Matter.............. 3-2
    3.3.1.2 Opacity......................... 3-3
  3.3.2 Recordkeeping and Reporting Requirements............................. 3-3
3.4 References for Chapter 3......................... 3-4

CHAPTER 4. EMISSION CONTROL TECHNIQUES AND TEST RESULTS......... 4-1

4.1 Control Devices.................................. 4-1
  4.1.1 Wet Scrubbers............................ 4-1
  4.1.2 Fabric Filters........................... 4-3
4.2 Analysis of NSPS Compliance Tests............... 4-4
4.3 Analysis of Site Visits......................... 4-6
4.4 Analysis of Emission Tests Conducted by EPA During NSPS Review......................... 4-8
  4.4.1 Particulate Emissions (Front-Half Catch)....................... 4-13
  4.4.2 Total Organic Carbon..................... 4-18
  4.4.3 Visible Emissions........................ 4-19
  4.4.4 Particle Size Determinations............. 4-20
  4.4.5 Polynuclear Aromatic Hydrocarbons........ 4-20
  4.4.6 Trace Metals............................. 4-23
  4.4.7 RAP, Asphalt Cement, and Aggregate Analysis................................ 4-23
  4.4.8 Scrubber Water Analyses.................. 4-28
4.5 References for Chapter 4........................ 4-34

CHAPTER 5. COST ANALYSIS.................................... 5-1

5.1 Cost Analysis of Emission Control Devices....... 5-1
5.2 Estimated Capital and Annualized Costs of Emission Control................................ 5-2
  5.2.1 Fabric Filters........................... 5-2
  5.2.2 Wet Scrubbers............................ 5-2
5.3 Comparison of Estimated and Reported Capital Cost Data............................... 5-3
5.4 Estimated Capital and Annualized Costs of Continuous Pressure Drop and Liquid Flow Rate Monitors................................ 5-3
5.5 Cost Effectiveness.............................. 5-4
5.6 References for Chapter 5........................ 5-12

CHAPTER 6. ENFORCEMENT ASPECTS.............................. 6-1

6.1 Enforcement..................................... 6-1
  6.1.1 Reciprocity Waivers...................... 6-1

TABLE OF CONTENTS (continued)

Page

6.1.2 Process Parameters........................ 6-1
  6.1.2.1 Production Rate................. 6-1
  6.1.2.2 Mix Type........................ 6-2
  6.1.2.3 Fuel............................ 6-2
6.1.3 Control Equipment......................... 6-3
6.1.4 Blue Haze Emissions....................... 6-4
6.1.5 Visible Emissions......................... 6-5
6.2 References for Chapter 6........................ 6-6

APPENDIX A. EMISSION SOURCE TEST DATA........................ A-1

APPENDIX B. SUMMARY OF STATE REGULATIONS FOR ASPHALT CONCRETE FACILITIES................................ B-1

APPENDIX C. EMISSION MEASUREMENT METHODS........................ C-1

LIST OF FIGURES

Page

Figure 2-1 Percent of total paving using recycled asphalt pavement on State, County, and local road projects.................................. 2-7

Figure 2-2 Operation flow chart and main parts of typical batch plant.................................... 2-9

Figure 2-3 Typical tons per hour capacity at various moisture contents.................................. 2-11

Figure 2-4 Recycling asphalt pavement in a batch plant......... 2-12

Figure 2-5 Typical drum-mix process............................ 2-14

Figure 2-6 Indirect heated plant............................... 2-17

Figure 4-1 Venturi scrubber control device on asphalt concrete plant...................................... 4-2

Figure 4-2 ΔP distribution among NSPS compliance tests......... 4-7

Figure 4-3 Particule size distribution curves of uncontrolled emissions collected during recycle and conventional operation................. 4-25

LIST OF TABLES

Page

Table 2-1 Production Capacity Distribution for Batch, Drum-Mix, and Continuous Plants.......................... 2-2

Table 2-2 Quantity of New Asphalt Plants Shipped............... 2-4

Table 2-3 Analysis of Process Water from Indirect Heated Asphalt Concrete Plants.............................. 2-18

Table 4-1 Compliance Test Report Summary........................ 4-5

Table 4-2 Control Device and RAP Utilization.................. 4-9

Table 4-3 Plant Design and Operting Parameters................. 4-10

Table 4-4 Scrubber Design and Operating Parameters............. 4-11

Table 4-5 Baghouse Design and Operating Parameters............. 4-12

Table 4-6 Summary of Emission Data from EPA-Conducted Tests.. 4-14

Table 4-7 Summary of Process Parameters from EPA-Conducted Tests.. 4-16

Table 4-8 Summary of Polynuclear Aromatic Hydrocarbon Emissions During Conventional Operation--Plant A..... 4-21

Table 4-9 Summary of Polynuclear Aromatic Hydrocarbon Emissions During Recycle Operation--Plant A.......... 4-22

Table 4-10 Summary of Trace Metal Emissions During Conventional Operation--Plant A...................... 4-24

Table 4-11 Summary of Trace Metal Emissions During Recycle Operation--Plant A.................................. 4-26

Table 4-12 RAP and Asphalt Cement Data........................ 4-27

Table 4-13 Average Scrubber Water Analytical Measurements--Plants A and B.................................... 4-29

Table 4-14 Scrubber Water PAH Analysis--Plant A................ 4-30

Table 4-15 Major Organics in Scrubber Water at Plant B.......... 4-32

Table 4-16 Scrubber Water Trace Metal Analysis--Plant A......... 4-33

Table 5-1 Summary of Asphalt Concrete Model Plant Parameters.. 5-5

LIST OF TABLES (continued)

Page

Table 5-2 Estimated Capital and Annualized Costs of Particulate Emission Control Equipment.............. 5-6

Table 5-3 Cost Factors Used in Calculating the Annualized Costs.................................. 5-7

Table 5-4 Comparison of Estimated Capital Cost of Emission Control with Reported Capital Cost Data............. 5-8

Table 5-5 Estimated Capital and Annualized Costs of Continuous Pressure Drop and Liquid Flow Rate Monitors...................................... 5-9

Table 5-6 Cost Effectiveness of Particulate Emission Reduction.. 5-10

1. EXECUTIVE SUMMARY

The Clean Air Act Amendments of 1977 require that the U. S. Environmental Protection Agency (EPA) review and, if appropriate, revise new source performance standards (NSPS) every 4 years. This report presents information on developments that have occurred in the asphalt concrete industry since the last review of the standards in 1979.

1.1 REGULATORY HISTORY OF CURRENT STANDARDS

The NSPS for the asphalt concrete industry were proposed on June 11, 1973, and promulgated on March 8, 1974. These standards were reviewed in 1979, and no changes were made. The standards apply to any asphalt concrete plant for which construction, modification, or reconstruction commenced after June 11, 1973. An asphalt concrete plant is defined as any facility used to manufacture asphalt concrete by heating and drying aggregate and mixing with asphalt cements. The asphalt concrete plant is comprised only of any combination of dryers; systems for screening, handling, storing, and weighing hot aggregate; systems for loading, transferring, and storing mineral filler; systems for mixing asphalt concrete; and the loading, transfer, and storage systems associated with emission control systems.

The standards prohibit the discharge into the atmosphere from any affected facility exhaust gases which:

1. Contain particulate matter in excess of 90 milligrams per dry standard cubic meter (mg/dscm) (0.04 grains per dry standard cubic foot [gr/dscf]); and
2. Exhibit 20 percent opacity or greater.

The first review of the standard, published in 1979, recommended that no changes be made to the particulate mass or the visible emission limits. The following sections summarize the results and conclusions of the second review of the NSPS for asphalt concrete plants.

1.2 INDUSTRY TRENDS

The most significant development in the asphalt concrete industry since the 1979 review is the increased use of drum-mix plants and recycled asphalt pavement (RAP). At the time of the 1979 review, only 2.5 percent of the existing plants were drum-mix plants. In 1983, approximately 96 percent of all new asphalt concrete plants purchased in the U.S. were drum-mix plants. The use of RAP approximately doubled between 1981 and 1983. Both of these trends are expected to continue.

The use of coal to fuel asphalt concrete plants is a recent (since 1983) development in the U.S. Prior to 1985, most of the coal burners were retrofit installations at existing facilities. The use of coal for fuel appears to be a technology that will grow rapidly, however, with as many as 30 additional plants expected to use coal by the end of 1985. Pre-NSPS facilities that convert to coal firing are considered modified facilities and must perform testing to demonstrate compliance with the NSPS. Existing NSPS plants that convert to coal firing would be required to demonstrate compliance with the NSPS while firing coal. Because the use of coal for fuel at asphalt concrete plants is an emerging technology, few units have been tested and little data are presently available.

The Bureau of Census and the Construction Industry Manufacturers Association estimate more than 800 new asphalt concrete plants have been shipped since the 1979 review and more than 100 more will be shipped in 1985.

1.3 CONTROL TECHNOLOGY

Fabric filters or wet scrubbers (venturi scrubbers) are used to control emissions from asphalt concrete plants. Compliance with the particulate mass and visible emission standards has been demonstrated using either control device. Most asphalt concrete plants utilize cyclones to recover particulate matter from the exhaust gas stream for product recovery and to reduce the particulate load to the emission control device. The recovered material is recycled to the process as filler; thus, these knockout boxes or cyclones are considered process equipment rather than emission control devices.

A detailed discussion of the control technology used in the asphalt concrete industry is presented in Chapter 4.

1.4 COMPLIANCE TEST DATA

During the present review of the asphalt concrete NSPS, 369 compliance test reports were collected from State agencies and reviewed. Approximately half of the plants operated at less than 80 percent of their design capacity during testing. Of the reports presenting numerical test results, 13 percent reported particulate emissions greater than the NSPS limit of 90 mg/dscm (0.04 gr/dscf). The majority of these non-complying plants were scrubber-controlled drum-mix plants. These reports also revealed that 82 percent of the scrubber-controlled plants were operated with a pressure drop (ΔP) across the scrubber of less than 5 kilopascals (kPa) (20 inches of water column [in. w.c.]). Of the 369 reports collected during this review, 89 reports presented either complete or summarized opacity data. Of these 89 reports, 7 had 6-minute averages greater than 20 percent. Three of these seven plants were producing conventional mix. These three plants also reported particulate emissions greater than 90 mg/dscm (0.04 gr/dscf). The remaining four plants with opacity greater than 20 percent were utilizing recycled asphalt pavement (RAP) during testing. Of these four plants, one had particulate emissions greater than 90 mg/dscm (0.04 gr/dscf), two had particulate emissions less than 90 mg/dscm (0.04 gr/dscf), and one did not report the particulate emission level. A detailed analysis of these compliance test reports is presented in Section 4.2.

1.5 COST CONSIDERATIONS AFFECTING THE NSPS

To estimate the cost impacts of the NSPS, model facility descriptions were developed based on information from the industry. The capital and annualized costs for the control system for each model plant were estimated using guidelines in Capital and Operating Costs of Selected Air Pollution Control Systems (GARD, Inc.) and information supplied by industry. Costs were updated to September 1984 dollars using the Chemical Engineering journal plant cost index. The cost effectiveness of fabric filter and wet scrubber control devices on each of three model plant sizes for seasonal operation (1,000 h/yr) and year-round operation (1,500 h/yr) was calculated. For seasonal operation, the cost effectiveness of controlling emissions from model plants with a fabric filter control device ranges from $130 to $253 per Mg ($118 to $230 per ton). With a wet scrubber control device, the cost effectiveness of emission control ranges from $108 to $213 per Mg ($99 to $194 per ton). For year-round operation, the cost effectiveness of control for fabric filters ranges from $89 to $183 per Mg ($81 to $168 per ton). For wet scrubbers, the cost effectiveness of control ranges from $84 to $166 per Mg ($76 to $151 per ton).

1.6 ENFORCEMENT ASPECTS

Chapter 6 discusses air pollution control agency personnel concerns regarding conditions that should exist during NSPS performance tests including process parameters (production rate, mix type, fuel used, and product temperature), control equipment (ΔP across scrubbers or fabric filter, water quality and pond size for scrubbers), and visible emissions.

2. THE ASPHALT CONCRETE INDUSTRY

2.1 INDUSTRY CHARACTERIZATION

2.1.1 Description of Industry

Companies that produce asphalt concrete are included in Standard Industrial Classification (SIC) Code 2951, "Paving Mixtures and Blocks."[1] In the production of asphalt concrete, aggregate, which is composed of gravel, sand, and mineral filler, is heated to eliminate moisture and then mixed with hot asphalt cement. The resulting hot mixture is pliable and able to be compacted and smoothed. When it cools and hardens, asphalt concrete provides a waterproof and durable pavement for roads, driveways, parking lots, and runways.

There are approximately 2,150 companies operating an estimated 4,500 asphalt concrete plants in the United States.[2] Approximately 40 percent of these companies operate only a single plant.[2] Because plants must be located near the job site, plants are concentrated in areas where the highway and road network is concentrated. Approximately 14 percent of asphalt concrete companies diversify their operations by producing portland cement (an asphalt concrete substitute), while 49 percent quarry aggregate, and 88 percent lay hot mix asphalt concrete.[2,3]

The three types of asphalt concrete plants in use are batch-mix, continuous-mix, and drum-mix. Batch-mix and continuous-mix plants separate the aggregate drying process from the mixing of aggregate with asphalt cement. Drum-mix plants combine these two processes. Plant production capacities range from 36 to 544 megagrams (Mg) (40 to 600 tons) of hot mix per hour.[2,3] The production capacity distribution for the three types of asphalt concrete plants is presented in Table 2-1.[2,3] Over 80 percent of all asphalt concrete plants are mobile.[2]

TABLE 2-1. PRODUCTION CAPACITY DISTRIBUTION FOR BATCH, DRUM-MIX, AND CONTINUOUS PLANTS[2,3]

Type of plant	Production range, Mg/h (tons/h)	Percentage of plants within production range
Batch plants	Under 136 (Under 150)	25
	136-272 (150-300)	63
	273-363 (301-400)	11
	Over 363 (Over 400)	1
		100
Drum-mix plants	Under 136 (Under 150)	15
	136-272 (150-300)	52
	273-363 (301-400)	26
	Over 363 (Over 400)	7
		100
Continuous mix plants	Under 136 (Under 150)	43
	136-272 (150-300)	21
	273-363 (301-400)	19
	Over 363 (Over 400)	17
		100

2.1.2 Asphalt Concrete Facilities Subject to NSPS

The new source performance standards (NSPS) for asphalt concrete plants apply to facilities for which construction, modification, or reconstruction commenced (as defined under 40 CFR 60.2) after June 11, 1973.[4,5] Due to the large number of affected facilities in the asphalt concrete industry, a complete list of affected facilities is beyond the scope of this review. In addition, any list of affected facilities would be of limited value due to the constantly changing number of plants and the mobile nature of the asphalt industry. Instead, an estimate of the number of new facilities has been made.

The total number of new asphalt plants shipped each year between July 1973 and December 1983, as reported by the Bureau of the Census, is presented in Table 2-2.[6] An estimated 1,437 new plants were shipped in the U.S. between July 1973 and December 1983. The Construction Industry Manufacturers Association estimates a 14.8 percent increase in new asphalt concrete plant sales for 1984 over 1983 and predicts a 13.4 percent increase in sales for 1985 over 1984.[7] Applying these increases to the estimated 81 new plants shipped in 1983 yields an estimate of 93 new plants in 1984 and 105 new plants in 1985. Therefore, by the end of 1985, an estimated 1,635 new plants will have been shipped since July 1973.

2.1.3. Industry Growth Projections

The Interstate Construction Estimate (ICE) reports that 350 and 372 million Mg (386 and 410 million tons) of asphalt concrete were produced in 1983 and 1984, respectively.[8] It is predicted that production for 1985 will remain about 363 million Mg (400 million tons) and that production for 1986 will increase significantly assuming an increase in funding for highways.[8]

Batch-mix and drum-mix plants comprise the majority of existing asphalt concrete plants, followed by a few remaining continuous-mix plants.[2,3] Continuous-mix plants are no longer sold. In 1983, approximately 96 percent of all new asphalt concrete plants purchased in the United States were drum-mix plants.[9] As discussed in Section 2.1.2, an increase in sales of new asphalt concrete plants of 14.8 percent is expected for 1984 over 1983 and an increase of 13.4 percent is predicted for 1985 over 1984.[7]

TABLE 2-2. QUANTITY OF NEW ASPHALT PLANTS SHIPPED[6]

Year	Total quantity shipped	Quantity exported[a]	Quantity shipped in U.S. only
1983	114	33[b]	81[b]
1982	171	50[c]	121[c]
1981	307	91	216
1980	241	82[d]	159[d]
1979	190	44[e]	146[e]
1978	184	41	143
1977	198	33	165
1976	131	35[f]	96[f]
1975	132	34[g]	98[g]
1974	194	54[g]	144[g]
last half of 1973	92	24[g]	68[g]
Total	1,954	517	1,437

[a] Data from the Bureau of the Census on exports are reported for 1977, 1978, and 1981; partial data or no data were available for the remaining years because some export information is proprietary. Therefore, exports in remaining years have been estimated.

[b] Based on 1981 and 1982 total export rate of 29 percent.

[c] Based on total export rate of 29 pecent for first 3 quarters of 1982.

[d] Based on total export rate for last 3 quarters of 1980 and on export rate of plants over 180 tph in first quarter of 1980 (34 percent).

[e] Based on total export rate of 23 percent for last 3 quarters of 1979.

[f] Based on total export rate of 27 percent for last quarter of 1976.

[g] Based on average export rate of 26 percent for 1976 through 1983.

2.2 RAW MATERIALS

2.2.1 Aggregate

Aggregate consists of any hard, inert mineral material mixed with a binding material in the production of asphalt concrete.[10] Aggregate typically comprises between 90 and 95 percent by weight of the asphalt concrete mixture.[10] Since aggregate provides most of the load-bearing properties of a pavement, the performance of the pavement depends on selection of the proper aggregate.[10]

2.2.2 Asphalt Cement

Asphalt cement binds the aggregate, prevents moisture from penetrating the aggregate, and acts as a cushioning agent. It typically comprises 4 to 6 percent by weight of the asphalt concrete mixture.[11]

Asphalt cement is the residue from the distillation of crude petroleum. Asphalt cement is classifed into "grades" under one of three systems. The most commonly used system classifies asphalt cement based on its viscosity at 60°C (140°F).[12] The more viscous the asphalt cement, the higher its numerical rating. An asphalt cement of grade AC-40 is considered a "hard" asphalt (i.e., a viscosity of 4,000 grams per centimeter per second [g/cm-s] [poises]), while an asphalt cement of grade AC-2.5 is considered a "soft" asphalt (i.e., a viscosity of 250 g/cm-s [poises]).[12] Several western States use a second grading system that measures viscosity of the asphalt cement after a standard simulated aging period.[13] This simulated aging period consists of exposure to a temperature of 163°C (325°F) for 5 hours.[13,14] Viscosity is measured at 60°C (140°F), with grades ranging from AR-1000 for a "soft" asphalt cement (1,000 g/cm-s [poises]) to AR-16000 for a "hard" asphalt cement (16,000 g/cm-s [poises]). A third grading system is based on the "penetration" allowed by the asphalt cement.[14] Grade designation 40 to 50 means that a needle with a weight attached will penetrate the asphalt cement between 40 and 50 tenths of a millimeter under standard test conditions.[12] The "hard" asphalt cements have penetration ratings of 40 to 50 while the "soft" grades have penetration ratings of 200 to 300.[12]

The asphalt cement grade selected for asphalt concrete mixes depends on the type of pavement, climate, and type and amount of traffic expected.[15] Generally, asphalt pavement bearing heavy traffic in warm climates would require a harder asphalt cement than pavement subject to either light traffic or cold climate conditions.[15]

2.2.3 Recycled Asphalt Pavement

Recycled asphalt pavement (RAP) is pavement material that has been removed from a roadway for use in new asphalt concrete pavement. Recycled asphalt pavement is used by a growing number of companies in their asphalt concrete mixtures. The Surface Transportation Assistance Act of 1982 encourages recycling by providing a 5 percent increase in Federal funds to State agencies that recycle asphalt concrete pavement. Figure 2-1 shows how the use of RAP in government paving contracts has increased since 1981. Rarely does the RAP comprise more than 60 percent by weight of the asphalt concrete mixture. Twenty-five percent RAP mixtures are typical in batch plants while 40 to 50 percent RAP mixtures are typical in drum-mix plants.[16-18]

Two methods are used to remove the old asphalt concrete pavement that is to be recycled. In one method, a milling machine planes off 5 to 10 cm (2 to 4 in.) of pavement with each pass it makes over the road. These machines have rotating cylinders with metal teeth that grind up the pavement leaving a rough but usable temporary surface for traffic. The ground-up pavement can be used immediately in the production of new asphalt concrete. The other method involves ripping up large chunks of pavement with heavy construction equipment. These chunks are transported to crushing machines that reduce the material to usable size for the production of asphalt concrete.[18] The road is typically closed to traffic if this process is used.

2.2.4 Rejuvenating Agents

Rejuvenating agents are sometimes used in RAP mixes to bring the weathered and aged asphalt cement in the RAP up to the specifications of the new pavement. Usually, a soft asphalt cement, a specially prepared high viscosity oil, or a hard asphalt cement blended with a low viscosity oil are used as rejuvenating agents. The amount of rejuvenating agent added depends on the properties of the RAP and on the

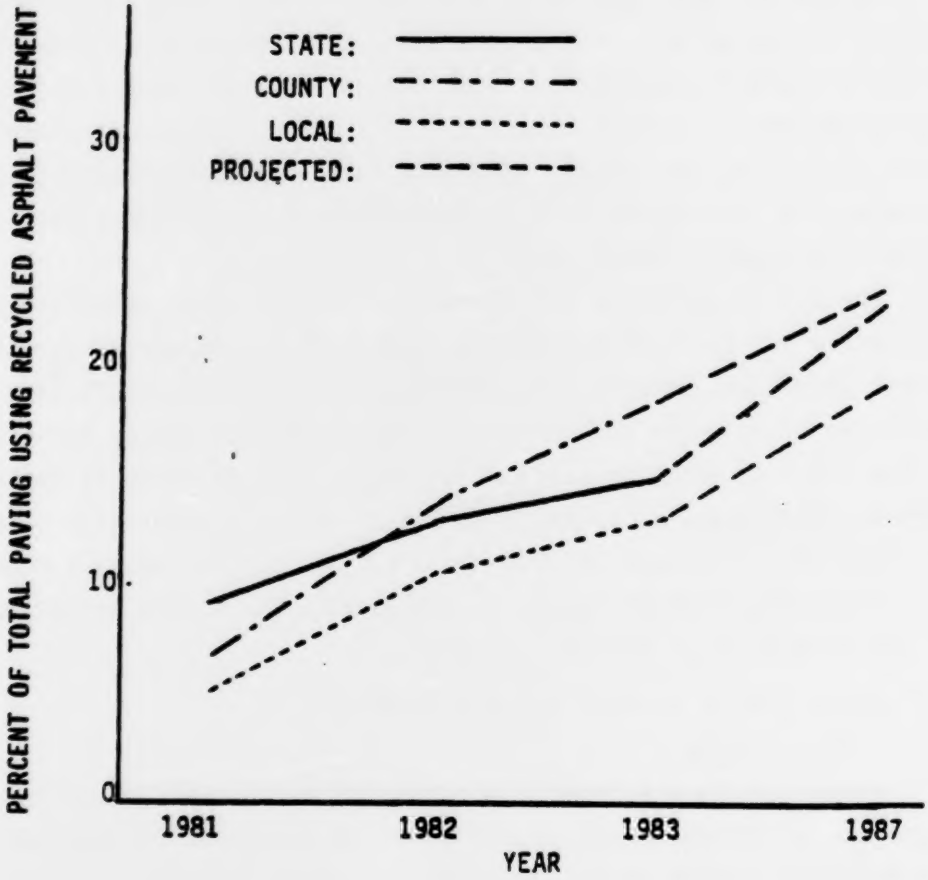


Figure 2-1. Percent of total paving using recycled asphalt pavement on State, county, and local road projects.[16]

specifications for the asphalt concrete product. These specifications are usually stipulated by the applicable State department of transportation. A State may permit the use of a rejuvenating agent at the contractor's discretion or may require the use of a rejuvenating agent.

2.2.5 Sulfur

Sulfur has been used on an experimental basis as a substitute for a portion of the asphalt cement in asphalt concrete mixes. Tests show that the asphalt cement/sulfur combination is better able to bind with aggregate than is asphalt cement alone.[19] Also, asphalt concrete pavements containing the asphalt cement/sulfur combination appear to be stronger and less susceptible to temperature changes than those containing asphalt cement alone.[19]

The use of sulfur is not competitive with asphalt cement in asphalt concrete mixes for several reasons, including environmental questions, worker objections (odor), and corrosion, all of which result from emissions of hydrogen sulfide (H_2S), sulfur dioxide (SO_2), and elemental sulfur (S). In addition, sulfur is almost twice as dense as asphalt cement. Consequently, to make the use of sulfur economically feasible, the cost of sulfur must be less than half the cost of asphalt cement.[20] The resolution of these issues will determine the future use of sulfur in the production of asphalt concrete.

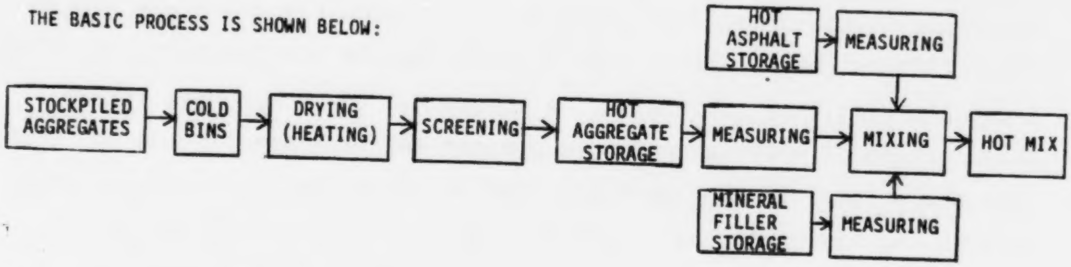
2.3 OPERATIONS OF ASPHALT CONCRETE PLANTS

2.3.1 Batch Plants

Figure 2-2 is a schematic of a typical batch plant operation. Aggregate of various sizes is stockpiled at the plant for easy access. The moisture content of the stockpiled aggregate usually ranges from 3 to 5 percent.[23] (Because aggregate piles are typically not covered, the moisture content can be higher after rainfall.) The moisture content of RAP is usually from 2 to 3 percent.[24]

The different sizes of aggregate are typically transported by front-end loader to separate cold feed bins and metered onto a feeder conveyor belt through gates at the bottom of the bins. The aggregate is screened before it is fed to the dryer to keep oversized material out of the mix.

THE BASIC PROCESS IS SHOWN BELOW:


STOCKPILED AGGREGATES
COLD BINS
DRYING (HEATING)
SCREENING
HOT AGGREGATE STORAGE
MEASURING
HOT ASPHALT STORAGE
MEASURING
MINERAL FILLER STORAGE
MEASURING
MIXING
HOT MIX

1. Cold storage bins
2. Cold elevator
3. Dryer
4. Dust collector
5. Hot elevator
6. Screening unit
7. Hot bins
8. Weigh box
9. Pugmill
10. Baghouse

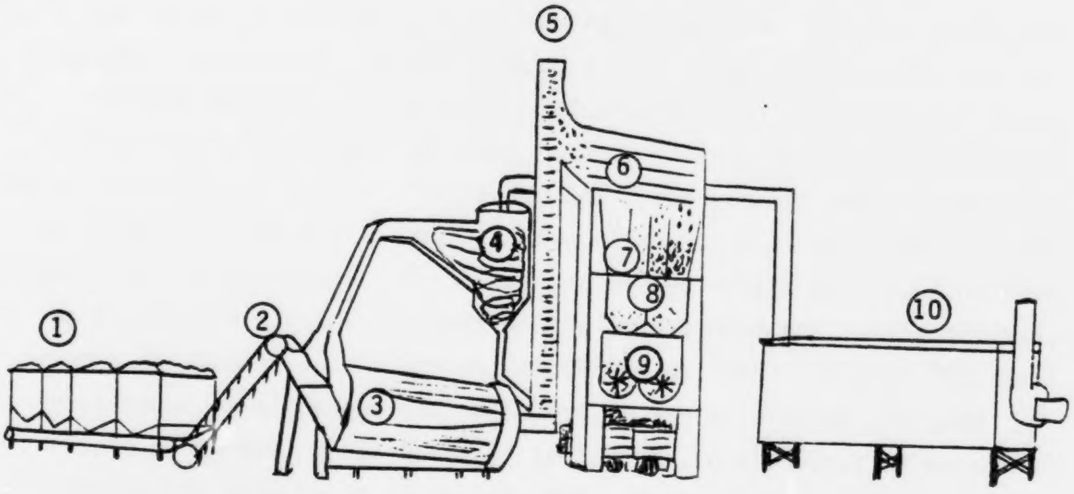

①
②
③
④
⑤
⑥
⑦
⑧
⑨
⑩

Figure 2-2. Operation flow chart and main parts of typical batch plant.[21,22]

The screened aggregate is fed to a rotating dryer with a burner at its lower (discharge) end that is fired with fuel oil, natural gas, or propane. The dryer removes moisture from the aggregate and heats the aggregate to the proper mix temperature. Inside the dryer are longitudinal flights (metal slats) that lift and tumble the aggregate, causing a curtain (veil) of material to be exposed to the heated gas stream. This curtain of material provides greater heat transfer to the aggregate than would occur if the aggregate tumbled along the bottom of the drum towards the discharge end. Typical aggregate temperature at the discharge end of the dryer is about 149°C (300°F). The amount of aggregate that a dryer can heat depends on the size of the drum, the size of the burner, and the moisture content of the aggregate. As the amount of moisture to be removed from the aggregate increases, the effective production capacity of the dryer decreases. Figure 2-3 shows a typical relationship between effective dryer production capacity and amount of moisture to be removed from the aggregate. As the figure demonstrates, a 2 percent increase in moisture content in the aggregate can decrease dryer production capacity by 25.3 percent.

Vibrating screens segregate the heated aggregate into bins according to size. A weigh hopper meters the desired amount of the various sizes of aggregate into a pugmill mixer. The pugmill typically mixes the aggregate for approximately 15 seconds before hot asphalt cement from a heated tank is sprayed into the pugmill.[26] The pugmill thoroughly mixes the aggregate and hot asphalt cement for 25 to 60 seconds.[26] The finished asphalt concrete is either directly loaded into trucks or held in insulated and/or heated storage silos. Depending on the production specifications, the temperature of the asphalt concrete mix can range from 107° to 177°C (225° to 350°F) at the end of the production process.[27]

When mix containing RAP is produced, the aggregate is superheated (compared to conventional operation) to about 315°C (600°F) to ensure sufficient heat transfer to the RAP when it is mixed with the virgin materials.[28] As shown in Figure 2-4, RAP may be added either to the pugmill mixer or at the discharge end of the dryer. Rarely is more than 30 percent RAP used in batch plants for the production of asphalt concrete.[18]

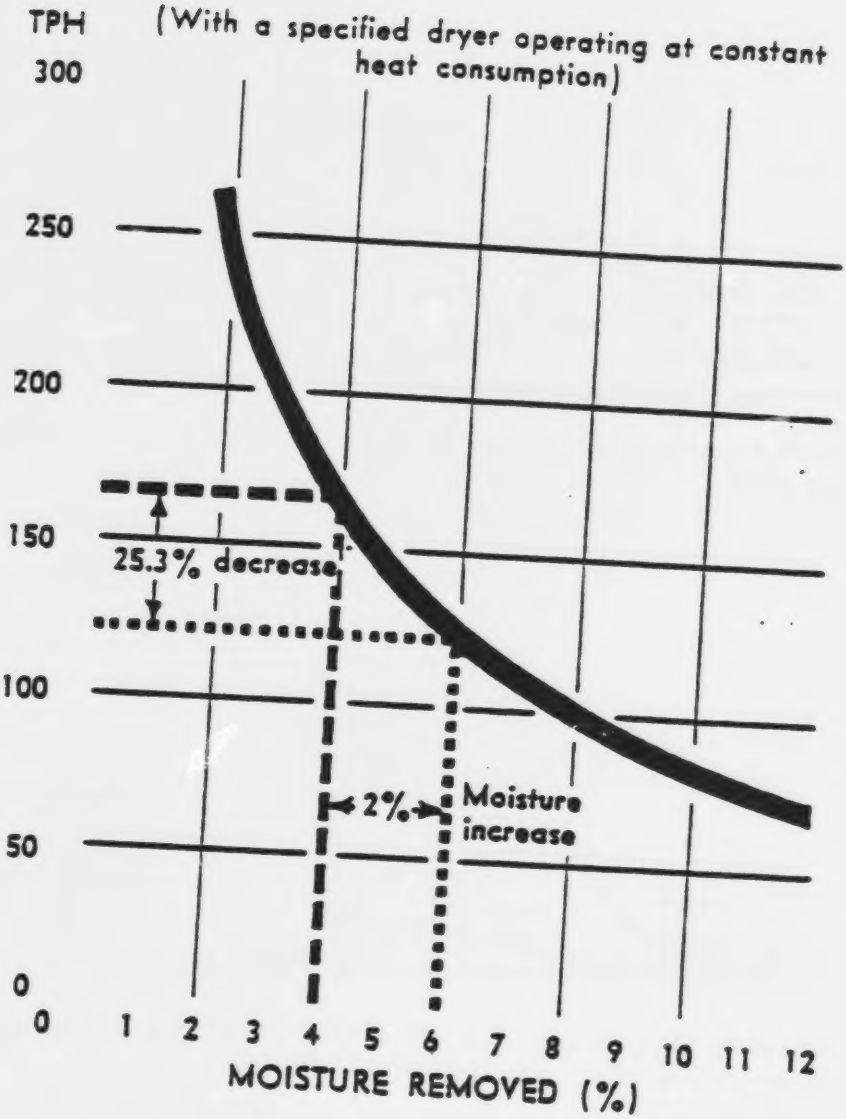
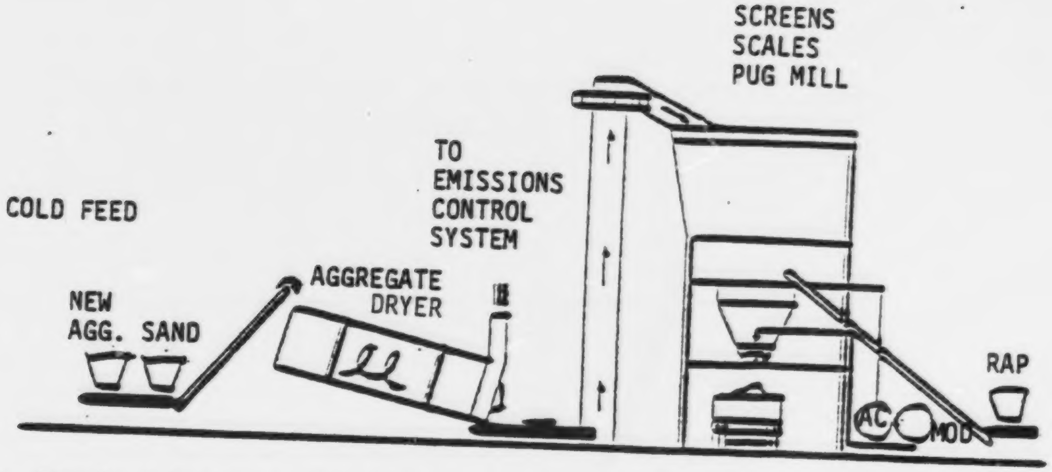
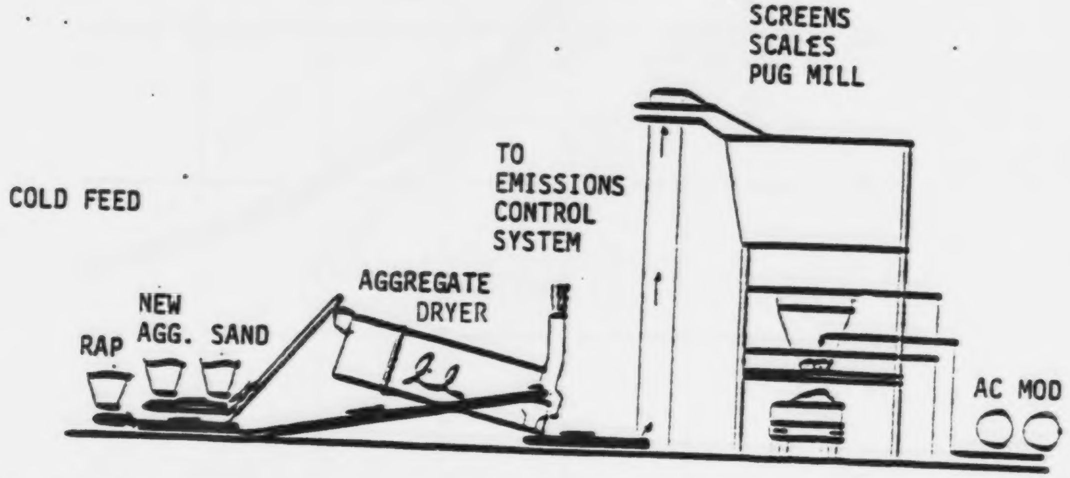


Figure 2-3. Typical tons per hour capacity at various moisture contents.[25]


SCREENS
SCALES
PUG MILL
TO
EMISSIONS
CONTROL
SYSTEM
COLD FEED
AGGREGATE
DRYER
NEW
AGG.
SAND
RAP
AC
MOD

(A) Standard batch plant with RAP added to superheated aggregate at the pug mill.


SCREENS
SCALES
PUG MILL
TO
EMISSIONS
CONTROL
SYSTEM
COLD FEED
AGGREGATE
DRYER
RAP
NEW
AGG.
SAND
AC MOD

(B) Standard batch plant with RAP added to superheated aggregate at dryer discharge.

Figure 2-4. Recycling asphalt pavement in a batch plant.[29]

Many batch plants have some form of mechanical dust collector that recovers particulate matter generated during the drying of the aggregate. The recovered fines are recycled to the production process, thus decreasing aggregate costs for the plant.

2.3.2 Continuous-Mix Plants

Continuous-mix plants are similar to batch plants. Continuous-mix plants have smaller hot bins (for holding the heated aggregate) than do batch plants. Little surge capacity is required of these bins because the aggregate is continuously metered and transported to the mixer inlet by a conveyor belt. Asphalt cement is continuously added to the aggregate at the inlet of the mixer. The aggregate and asphalt cement are mixed by the action of rotating paddles while being conveyed through the mixer. An adjustable dam at the outlet end of the mixer regulates the mixing time and also provides some surge capacity. The finished mix is transported by a conveyor belt to either a storage silo or surge bin.

2.3.3 Drum-Mix Plants

Figure 2-5 depicts a typical drum-mix plant equipped for production using only virgin raw materials. Drum-mix plants dry the aggregate and mix it with the asphalt cement in the same drum, eliminating the need for the extra conveyor belt, hot bins and screens, weigh hopper, and pugmill. Although the drum of a drum-mix plant is much like the dryer of a batch plant, the burner is at the aggregate feed end rather than at the aggregate discharge end. The veil of aggregate is heated as it flows with the heated gas stream instead of countercurrent to the gas stream as in a batch plant.

The burner in a drum-mix plant emits a much bushier flame than does the burner in a batch plant. The bushier flame is designed to provide earlier and greater exposure of the virgin aggregate to the heat of the flame. This design also protects the asphalt cement, which is injected approximately two thirds of the way down the length of the drum, away from the direct heat of the flame. Drum-mix plants typically have more flights in their drums than do batch dryers to increase veiling of the aggregate and to improve heat transfer.[31]

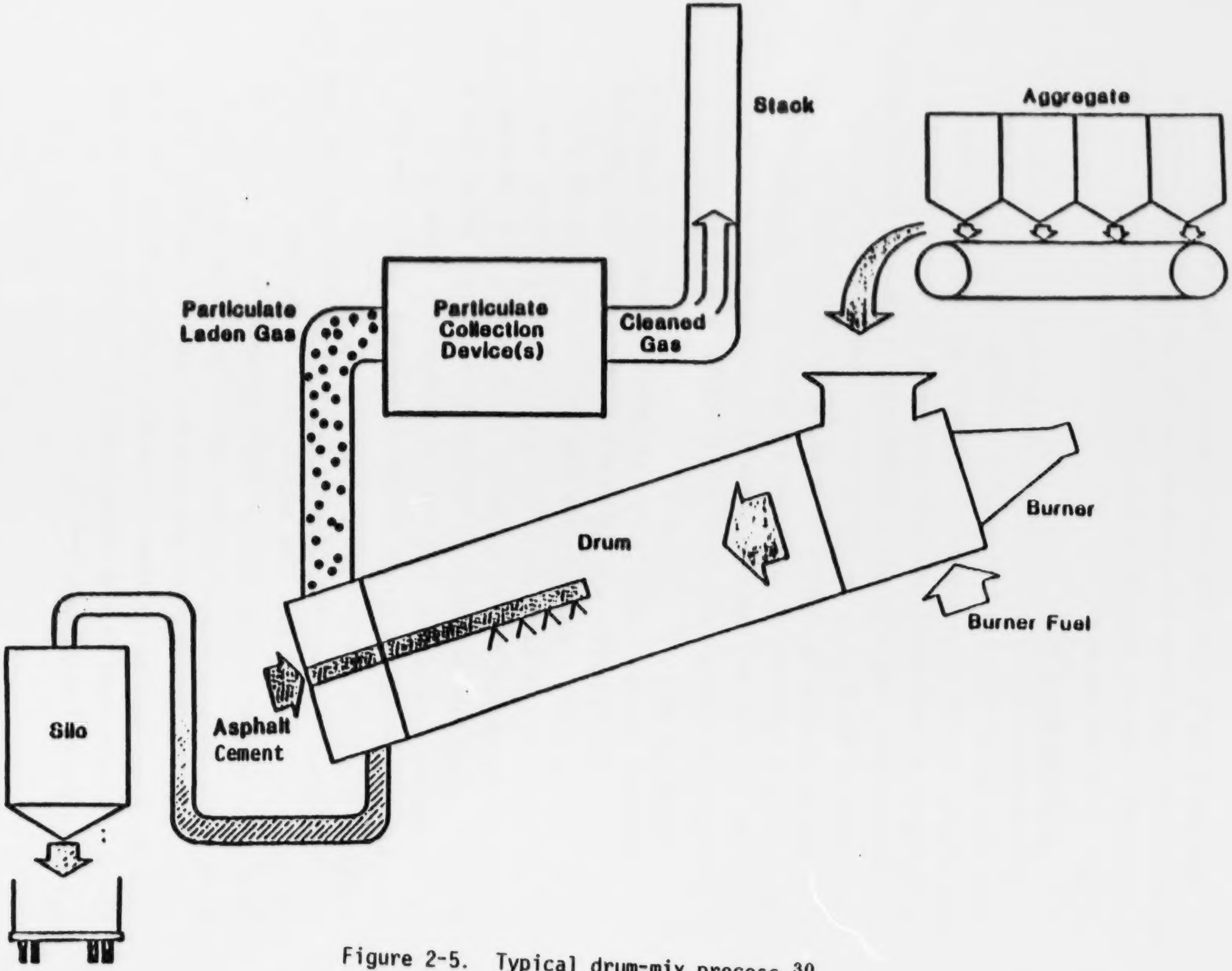

Stack
Aggregate
Particulate Laden Gas
Particulate Collection Device(s)
Cleaned Gas
Drum
Burner
Burner Fuel
Silo
Asphalt Cement

Figure 2-5. Typical drum-mix process.[30]

The asphalt cement, which is usually injected from a pipe inserted from the discharge end of the rotating drum, coats the aggregate. The temperature of the mix as it leaves the drum usually ranges from 107° to 177°C (225° to 350°F).[27] The hot asphalt concrete is transported by conveyor to a surge bin or to an insulated, and possibly heated, storage silo for truck load-out. Like batch plants, drum-mix plants have mechanical dust control devices that capture material to be recycled to the process. In addition, the fine dust captured by the baghouse is returned to the process.

The first recycle plants introduced the RAP with the virgin aggregate at the burner end of the drum. This often caused "blue haze" as volatile compounds in the RAP burned off when RAP came in contact with the burner flame.[18,30] In attempts to prevent the generation of blue haze, manufactures have experimented with several modifications of the technology for introducing RAP to the drum-dryer. In one modification, water is sprayed on the RAP and aggregate immediately before it enters the burner end of the drum. The water raises the moisture content of the aggregate and RAP from about 5 percent to 7 or 8 percent.[32] Another modification is to place a heat shield around the burner to shield the RAP from direct contact with the flame. However, this method restricts the flow of the burner gas, which increases the gas velocity and turbulence and results in higher dust carryover than is experienced without the shield.[18] A third modification incorporates a separate drum inside of the mixing drum to shield the RAP from the hot gas stream. Virgin material is heated directly in the inner drum while the RAP is introduced between the two drums to shield it from the direct flame. The RAP is heated indirectly by contact with the inner drum before being mixed with the superheated virgin aggregate at the discharge point of the inner drum.[18,33] This method reduces the capacity of the drum-mix plant because the presence of the inner drum reduces the effective volume of the outer drum.

Currently in new drum-mix plants, the RAP is introduced through a collar midway down the drum and is dried by both the superheated aggregate and by the gas stream. The veil of virgin aggregate created by the flights in the drum keeps the high heat of the flame from reaching the RAP. Two vendors have attempted to improve on this approach by also expanding the drum diameter at the burner end to allow a shorter, bushier flame and to obtain more efficient heat transfer from the burner flame to the virgin aggregate.[34]

One major advantage of drum mix plants is that they can produce material containing higher percentages of RAP than batch plants can produce. With the greater veiling of aggregate, drum-mix plants are more efficient than batch plants at transferring heat and achieving proper mixing of RAP and virgin materials.

2.3.4 Indirect Heated Plant

A potential new commercial production process for asphalt concrete involves indirect heating of the aggregate and asphalt cement in a mixer.[35] Figure 2-6 depicts this production process.

In this process, asphalt cement and preheated aggregate are introduced through air-locks into a heated, sealed mixing unit. Synthetic heat transfer fluids are heated to 316° to 343°C (600° to 650°F) by a fuel efficient diesel- or gas-fired burner.[35] These synthetic fluids heat the mixing unit chamber to approximately 149°C (300°F).[35] Steam from the moisture driven off from the aggregate is piped to the cold feed bins to preheat the virgin aggregate. This preheating of the aggregate decreases energy costs for drying. The product asphalt concrete mix is transported by an enclosed conveyor from the mixing unit to a storage silo. Because this process is sealed, there are no process air emissions. The steam from the mixing unit condenses as it preheats the cold feed bins. The results of tests on this condensed water are presented in Table 2-3. The only other process emissions are the gases from the heater unit. No air emission tests have been performed on the heater units at this type of plant.

The indirect heated process has been successfully demonstrated with a pilot-scale plant capable of producing 14 to 18 megagrams per hour (Mg/h) (15 to 20 tons per hour [tons/h]) of asphalt concrete.[38] Stationary and portable indirect heated plants have been designed with production capacities ranging from 45 to 204 Mg/h (50 to 225 tons/h), and commercial plants of 181 to 272 Mg/h (200 to 300 tons/h) production capacity are expected by 1986.[37,38]

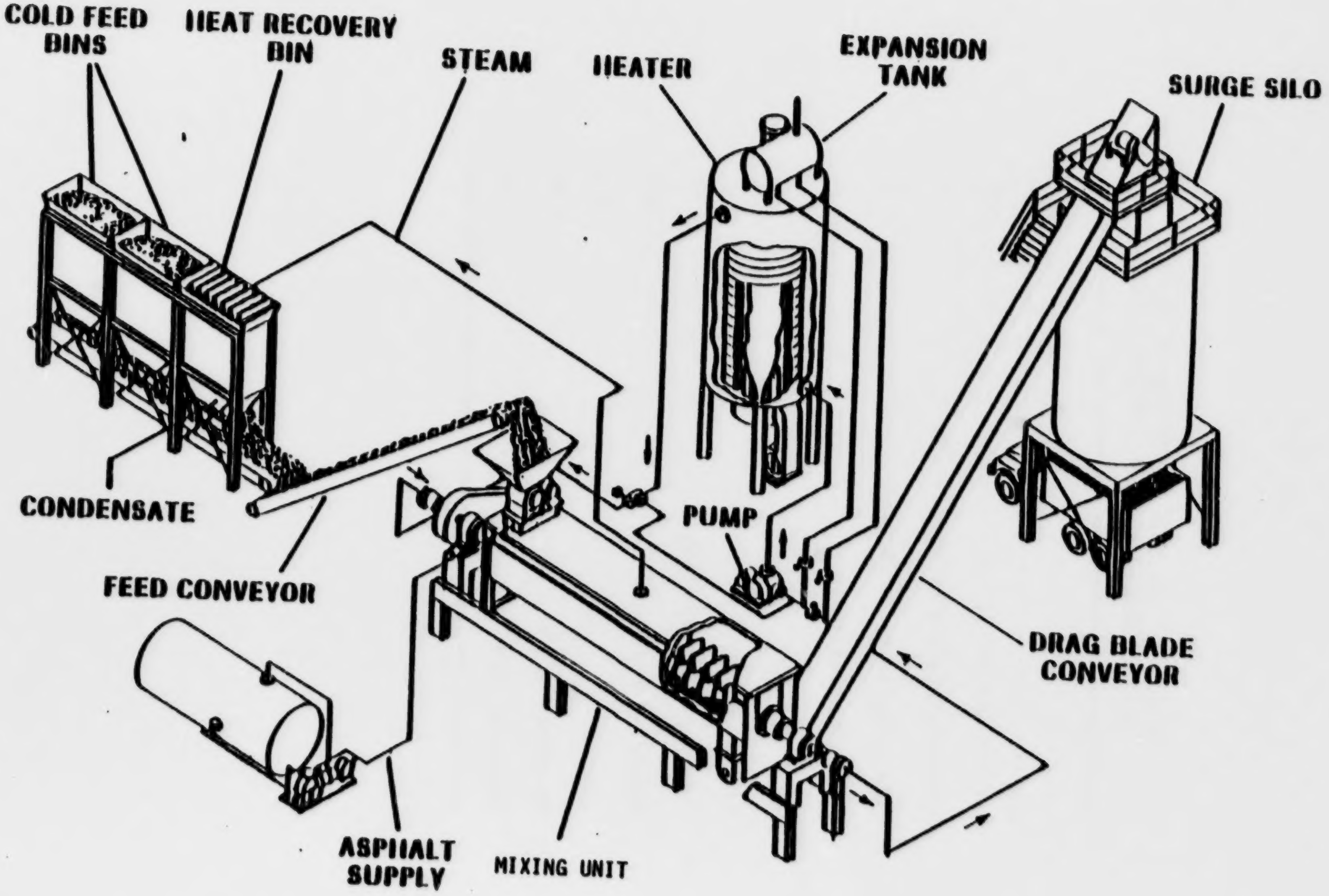

COLD FEED BINS
HEAT RECOVERY BIN
STEAM
HEATER
EXPANSION TANK
SURGE SILO
CONDENSATE
PUMP
FEED CONVEYOR
DRAG BLADE CONVEYOR
ASPHALT SUPPLY
MIXING UNIT

Figure 2-6. Indirect heated plant.[35_37]

TABLE 2-3. ANALYSIS OF PROCESS WATER FROM INDIRECT HEATED ASPHALT CONCRETE PLANTS[36]

	Test, mg/ℓ
Total dissolved solids	28
Phenolphthalein alkalinity	0
Total alkalinity as $CaCO_3$	10
Carbonate alkalinity	0
Chloride as Cl	1.7
Sulfate as SO_4	3.5
Total hardness as $CaCO_3$	10
Magnesium as Mg	0.5
Iron as Fe	1.1
Manganese as Mn	0.05
Turbidity, NTU	11

2.3.5 Coal as Fuel

A limited number of plants have experimented with coal as a fuel. The majority of coal-fired asphalt concrete plants use dry pulverized coal, although one manufacturer produces a wet coal slurry system.[39-42] This slurry consists of 70 percent pulverized coal, 29 percent water, and 1 percent additive to keep the coal in suspension.[41]

Because the use of coal in asphalt concrete plants is a very recent (since 1983) development in the U.S., there are few emission test reports for plants utilizing coal.[40,42] The use of coal for fuel appears to be a technology that may grow rapidly, however, with as many as 30 additional plants expected to use coal by the end of 1985.[40]

2.4 EMISSIONS

2.4.1 Air Emissions

2.4.1.1 Batch Plants. The air emissions from the dryer include sulfur oxides, nitrogen oxides, hydrocarbons, particulate matter, aldehydes, carbon monoxide, and polycyclic organic material (POM).[43] The uncontrolled particulate emission level from batch plants averages 22.5 kilograms (kg) per Mg (45 pounds [lb] per ton) of asphalt concrete produced.[43] No uncontrolled emission data are available for gaseous emissions from batch plant dryers.

Fugitive emissions not related to the production process include dust from trucks carrying aggregate or asphalt concrete, aggregate blown from stockpiles or from raw materials being transported to the dryer, and emissions from openings in the storage silo or surge bin. The potential uncontrolled fugitive particulate emission level from batch plants is 0.163 kg per Mg (0.326 lb per ton) of asphalt concrete produced.[44,45]

"Blue haze" emission have been reported when RAP and virgin materials are mixed.[46] These emissions may occur when the RAP material is heated to a temperature that exceeds its smoke point. In addition, some batch plant operators have found that their exhaust gas handling systems are undersized to handle the large amount of exhaust gas generated when the moisture in the RAP turns to steam.

2.4.1.2 Continuous-Mix Plants. The uncontrolled particulate emission level from continuous-mix plants is approximately the same as that from batch plants.[18]

2.4.1.3 Drum-Mix Plant. The uncontrolled particulate emission level from drum-mix plants averages about 2.45 kg per Mg (4.9 lb per ton) of asphalt concrete produced.[47] Production levels, aggregate properties, and gas stream velocity affect particulate emission levels from drum-mix plants in the same way they affect those from batch plants.[47] As measured by EPA Reference Method 5E, uncontrolled condensible hydrocarbon emissions range from about 0.006 to 0.14 kg (0.012 to 0.27 lb) of carbon per Mg (ton) of asphalt concrete.[48,49] Production levels and operating temperatures may influence these hydrocarbon emissions.[50]

The fugitive emissions from drum mix plants are similar in type, source, and amount to fugitive emissions from batch plants with the exception of fugitive emissions associated with the mixing units at batch and drum-mix plants.

2.4.2 Effect of Asphalt Cement Grade on Emissions

The way in which various grades of asphalt cement affect emissions from batch and drum-mix plants is not known. Due to a probable increase in the amount of light hydrocarbons in soft asphalt cements, higher total organic carbon (TOC) emissions are expected when a soft asphalt cement, such as AC-2.5, is used than when a hard asphalt cement, such as AC-20, is used. Although asphalt cements are graded by viscosity and tested for flash point, ductility, specific gravity, softening point, and weight loss and change in penetration upon heating, no analyses of the chemical constituents of various asphalt cements are routinely made as part of quality control for the production process. Laboratory test data indicate that two asphalt cements distilled from two different crude oils can receive the same grade designation and yet have different chemical constituents. The lack of sophisticated equipment and technical expertise in existing asphalt testing laboratories precludes the chemical analysis of asphalt cements. Also, the relationship between the chemical constituents of an asphalt cement and its behavior in the pavement is uncertain, further discouraging chemical analysis of asphalt cement.[51]

2.5 REFERENCES FOR CHAPTER 2

1. Office of Management and Budget. Standard Industrial Classification Manual. 1972. United States Government Printing Office: Washington, D.C. p. 127.

2. Telecon. Maul, M., MRI, with Kloiber, F., National Asphalt Pavement Association. October 7, 1983. Production facts and figures for asphalt concrete industry, 1981-1982.

3. Letter and attachments from Kloiber, F., National Asphalt Pavement Association, to Kinsey, J., MRI. May 3, 1982. Production facts and figures for asphalt concrete industry, 1979-1981.

4. Environmental Protection Agency. Inspection Manual for Enforcement of New Source Performance Standards, Asphalt Concrete Plants. EPA 340/1-76-003. Washington, D.C. March 1976. p. 3.

5. Environmental Protection Agency. Code of Federal Regulations. Title 40, Chapter I, Part 60. Washington, D.C. Office of the Federal Register. July 1, 1982.

6. U.S. Department of Commerce, Bureau of the Census. Current Industrial Reports, Construction Machinery. MA 35D(74)-1 through MA 35D(83)-1, 1974 through 1983.

7. Material from Witas, D. A., Construction Industry Manufacturers Association, to Butler, J. R., MRI. March 15, 1985. Bureau of Census and CIMA forecast of 1984 and 1985 machine shipments.

8. Telecon. Butler, J., MRI, with Kloiber, F., National Asphalt Pavement Association. November 20, 1984. Production facts and figures for asphalt concrete industry.

9. Telecon. Maul, M., MRI, with Mize, G., ASTEC Industries, Inc. October 10, 1983. Profile of asphalt concrete industry.

10. The Asphalt Institute. Principles of Construction of Hot-Mix Asphalt Pavements. Manual Series No. 22, College Park, Maryland. January 1983. p. 168.

11. The Asphalt Institute. Mix Design Methods for Asphalt Concrete. College Park, Maryland. March 1979. pp. 27, 59.

12. The Asphalt Institute. Paving Asphalt. Educational Series No. 8. College Park, Maryland. January 1980. pp. 2-3.

13. Reference 10, p. 15.

14. The Asphalt Institute. Asphalt as Material Information Series No. 93. College Park, Maryland. July 1975. p. 7-8.

15. Barber-Greene Company. Bituminous Construction Handbook. Aurora, Illinois. 1979. pp. 39-40.

16. Letters and attachments from Hoyt, P., Asphalt Recyling and Reclaiming Association, to Maul, M., MRI. November 4, 1983. Information on the Asphalt Recycling and Reclaiming Association and a 1982 survey of governments concerning use of recycled asphalt pavement.

17. Trip report. Terry, W., MRI, to Telander, J., EPA:ISB. October 31, 1983. Report of visit to CMI Corp., Oklahoma City, Oklahoma.

18. Kinsey, J. S. Asphalt Concrete Industry--Source Category Report. U. S. Environmental Protection Agency. Research Triangle Park, North Carolina. February 28, 1983. pp. 15-18.

19. Fromm, H. J., D. C. Bean, and L. Miller. Sulphur-Asphalt Pavements Performance and Recycling. Proceedings of the Association of Asphalt Paving Technologists, Vol. 49. 1980. p. 98.

20. Mize, G. Safe Paving with Sulfur. Information Series 81. National Asphalt Pavement Association. Riverdale, Maryland. 1981. p. 1.

21. Reference 10, p. 139.

22. Reference 15, pp. 170-171.

23. Reference 18, pp. 5.

24. Trip report. Terry, W., MRI, to Telander, J., EPA:ISB. August 28, 1984. Report of visit to ASTEC Industries, Inc., Chattanooga, Tennessee.

25. Reference 15, p. 154.

26. Reference 18, p. 7.

27. Reference 15, p. 239.

28. Scherocman, J. A. (Barber-Greene Company). Producing Recycled Asphalt Concrete Mixtures in Batch and Drum-Mix Plants. North Carolina Asphalt Pavement Recycling Seminar, McKimmon Center: Raleigh. February 9-10, 1983.

29. Reference 18, p. 20.

30. Beggs, T. W. (JACA Corp.). Emission of Volatile Organic Compounds from Drum-Mix Asphalt Plants. Prepared for U. S. Environmental Protection Agency. Cincinnati, Ohio. EPA-600/2-81-026. February 1981. pp. 2-5.

31. Reference 28, p. 7-10.

32. Trip report. Shular, J., MRI, to Telander, J., EPA:ISB. August 28, 1984. Report of visit to Ajax Materials Corp., Detroit, Michigan.

33. The Asphalt Institute. Asphalt Hot-Mix Recycling. Manual Series No. 20. College Park, Maryland. August 1981. p. 27, 30.

34. Trip report. Terry, W., MRI, to Telander, J., EPA:ISB. October 31, 1983. Report of visit to CMI Corp., Oklahoma City, Oklahoma.

35. Letter and brochure from Musil, J., Iowa Manufacturing Company to Telander, J., EPA:ISB. November 4, 1983. Costs and benefits of indirect heating asphalt concrete plant.

36. Letter and attachment from Bracegirdle, P., Mix Design Methods, Inc., to Telander, J., EPA:ISB. November 17, 1983. Indirect heated plant.

37. Letter and attachment from Bracegirdle, P., MDM Industries, Inc., to J. Butler, MRI. August 20, 1984. Update on indirect heated plant.

38. Telecon. Butler, J., MRI, with Bracegirdle, P., MDM Industries, Inc. January 16, 1985.

39. Letter and attachments from Sprouse, S. M., Astec Industries, Inc. March 26, 1985. Emission test report and product literature.

40. Telecon, Butler, J., MRI, to Brock, D., Astec Industries. March 21, 1985. Discussion of coal as a fuel in asphalt concrete plants.

41. Literature from Clements, J., Standard Havens to Bulter, J., MRI. March 15, 1985. Product literature and test results.

42. Telecon, Butler, J. MRI, to Clements, J., Standard Havens. March 19, 1985. Discussion of coal as a fuel in asphalt concrete plants.

43. Kahn, Z. S., and T. W. Hughes, (Monsanto Research Corp.). Source Assessment Asphalt Hot Mix. Prepared for U. S. Environmental Protection Agency. Cincinnati, Ohio. EPA-600/2-77-107n. December 1977. pp. 45-52.

44. Evaluation of Fugitive Dust from Mining. EPA Contract No. 68-02-1321, PEDCo Environmental Specialists, Inc., Cincinnati, Ohio. June 1976.

45. Peters, J. A. and P. K. Chalekode, "Assessment of Open Sources," Presented at the Third National Conference on Energy and the Environment, College Corner, Ohio. October 1, 1975.

46. The Asphalt Institute. Asphalt Hot Mix Emission Study. College Park, Maryland. March 1975. p. iii.

47. Preliminary Evaluation of Air Pollution Aspects of the Drum Mix Process. EPA-340/1-77-004. U.S. Environmental Protection Agency, Research Triangle Park, North Carolina. March 1976.

48. Radian Corp. Asphalt Concrete Industry Emission Test Report, Sloan Construction Company. Prepared for U. S. Environmental Protection Agency. Research Triangle Park, North Carolina. EMB Report 84-ASP-8. July 1984. pp. 2-2 and 2-3.

49. GCA Corp. Emission Test Report, Western Engineering Asphalt Concrete Plant. Prepared for U. S. Environmental Protection Agency. Research Triangle Park, North Carolina. EMB Project No. 83-ASP-5. pp. 7-8.

50. Reference 30, pp. 23-27.

51. Reference 10, pp. 16-17.

3. CURRENT STANDARDS FOR ASPHALT CONCRETE PLANTS

3.1 FACILITIES AFFECTED

On June 11, 1973, the Environmental Protection Agency (EPA) proposed standards for asphalt concrete plants under Section 111 of the Clean Air Act to control particulate matter and visible emissions. The final version of the standards was published on March 8, 1974, effective February 28, 1974, for plants whose construction or modification was commenced after June 11, 1973.[1,2] These standards were reviewed in 1979, and no changes were made.[3]

The standards apply to facilities for which construction, modification, or reconstruction commenced (as defined under 40 CFR 60.2) after June 11, 1973. Such facilities are termed "affected facilities." Standards of performance are not applicable to "existing facilities" (i.e., facilities for which construction, modification, or reconstruction commenced on or before June 11, 1973). An existing facility may become an affected facility and, therefore, be subject to standards if the facility undergoes modification or reconstruction. The term "modified facility" applies to facilities to which physical or operational changes have been made that caused an increase in the emission rate of particulate matter or visible emissions (i.e., the pollutants to which these standards apply). The term "reconstructed facility" applies when the replacement cost of components exceeds 50 percent of the cost of building a comparable new facility. Modification and reconstruction are defined under 40 CFR 60.14 and 60.15, respectively.[4]

The affected facility under the new source performance standards (NSPS) for asphalt concrete plants is each asphalt concrete plant (i.e., any facility used to manufacture asphalt concrete by heating and drying aggregate and mixing with asphalt cements). An asphalt concrete plant is comprised only of any combination of the following:[5]

1. Dryers;
2. Systems for screening, handling, storing, and weighing hot aggregate;
3. Systems for loading, transferring, and storing mineral filler;
4. Systems for mixing asphalt concrete; and
5. Systems for loading, transfer, and storage associated with emission control systems.

3.2 CONTROLLED POLLUTANTS AND EMISSION LEVELS

Particulate emissions from asphalt concrete plants are controlled under the NSPS, as defined by 40 CFR, Subpart I, Section 60.92. The standards prohibit the discharge into the atmosphere from any affected facility exhaust gases which:

1. Contain particulate matter in excess of 90 milligrams per dry standard cubic meter (mg/dscm) (0.04 grains per dry standard cubic foot [gr/dscf]), and
2. Exhibit 20 percent opacity or greater.

3.3 TESTING AND MONITORING REQUIREMENTS

3.3.1 Testing Requirements

Performance tests to verify compliance with the NSPS must be conducted and a written report of the results submitted within 60 days after an asphalt plant has reached its full capacity production rate or within 180 days after the initial startup of the facility, whichever comes first.[6] Under Section 114 of the Clean Air Act, reports of performance tests may also be required by the Administrator at other times.[6] Emissions measured during startup, shutdown, and malfunctions are not considered representative for the purpose of demonstrating compliance.

3.3.1.1 Particulate Matter. The EPA reference test methods used to determine compliance with the standards covering particulate matter emissions are:[7]

1. Method 5 for the concentration of particulate matter and the associated moisture content of the exhaust gases;

2. Method 1 for sample and velocity traverses;

3. Method 2 for stack gas velocity and volumetric flow rate determinations; and

4. Method 3 for analysis of exhaust gases for carbon dioxide (CO_2), excess air, and dry molecular weight.

The sampling time for each Method 5 test run shall be at least 60 minutes, and the sampling rate shall be at least 0.9 dry standard cubic meters per hour (dscm/h) (0.53 dry standard cubic feet per min [dscf/min]).[7] Performance tests consist of three separate runs conducted during representative plant operating conditions. The standards apply to the arithmetic mean of the test runs. Waiver provisions are made to allow compliance to be determined on the arithmetic mean of two runs upon the approval of EPA. A waiver may be granted for accidental sample loss or because of conditions which cause one of the three runs to be discontinued because of sample train failure, forced plant shutdown, extreme meteorological conditions, or other circumstances beyond the owner or operator's control.[6,7]

3.3.1.2 Opacity. Methods for determining compliance with opacity standards are defined in Section 60.11 of the Code of Federal Regulations.[8] Method 9 is used for measuring visible emissions from stationary sources. Continuous monitoring of opacity is not required.

3.3.2 Recordkeeping and Reporting Requirements

The owner or operator of an asphalt plant must notify the Administrator between 30 and 60 days prior to initial startup. Notification of actual initial startup must be made within 15 days after initial startup. Notification must also be made of any physical or operational change to an existing asphalt plant that may increase the emission rate of any air pollutant to which the standards apply.[9]

A file of all records and reports on performance tests, monitoring, and maintenance are to be kept for a period of at least 2 years. Additional discussion concerning the documentation of representative process and control device operating conditions during compliance testing is included in Chapter 7. Records are also to be maintained by the plant owner or operator of the occurrence and duration of startup, shutdown, or malfunctions in the process and of malfunctions of the air pollution control equipment.[9]

3.4 REFERENCES FOR CHAPTER 3

1. Environmental Protection Agency. Inspection Manual for Enforcement of New Source Performance Standards, Asphalt Concrete Plants. EPA 340/1-76-003. Washington, D.C. March 1976. p. 3.
2. Environmental Protection Agency. Code of Federal Regulations. Title 40, Chapter I, Part 60. Washington, D.C. Office of the Federal Register. July 1, 1982.
3. Environmental Protection Agency. A Review of Standards of Performance for New Stationary Sources, Asphalt Concrete Plants. EPA-450/3-79-014. Research Triangle Park, North Carolina. June 1979.
4. Reference 2, Sections 60.14 and 60.15.
5. Reference 2, Section 60.90.
6. Reference 2, Section 60.8.
7. Reference 2, Section 60.93.
8. Reference 2, Section 60.11.
9. Reference 2, Section 60.7.

4. EMISSION CONTROL TECHNIQUES AND TEST RESULTS

This chapter describes the design and operating parameters for the air emission control devices used in the asphalt concrete industry. Also included in this chapter are tabulations of compliance test results collected from State agencies, a summary of site visits, and a summary of emission data from EPA-conducted source tests.

4.1 CONTROL DEVICES

Wet scrubbers and fabric filters are the typical particulate control devices used by asphalt concrete plants to meet the new source performance standards (NSPS). Most new asphalt concrete plants use knockout boxes or cyclones as product recovery devices to recover large particulate matter from the exhaust gas stream and to reduce the particulate load to the emission control device. The recovered material is recycled to the process as filler; thus, these knockout boxes or cyclones are considered process equipment rather than emission control devices.

4.1.1 Wet Scrubbers

Wet scrubbers cleanse particulate-laden gas streams by entrapping particulate matter with water droplets. Although a variety of scrubbers are available, the most commonly used wet scrubber on both batch and drum-mix plants is the venturi scrubber. Figure 4-1 is a schematic of a typical venturi scrubber. In some system designs, water is sprayed into the ductwork upstream of the throat section of the venturi scrubber to keep the ductwork clean.[1,2] These sprays may remove some particulate matter from the gas stream through condensation and impingement mechanisms.

Some control of condensible hydrocarbons may occur as a result of the cooling and condensing action of the water sprays. The droplets formed would then be removed in the same manner as dry particulate

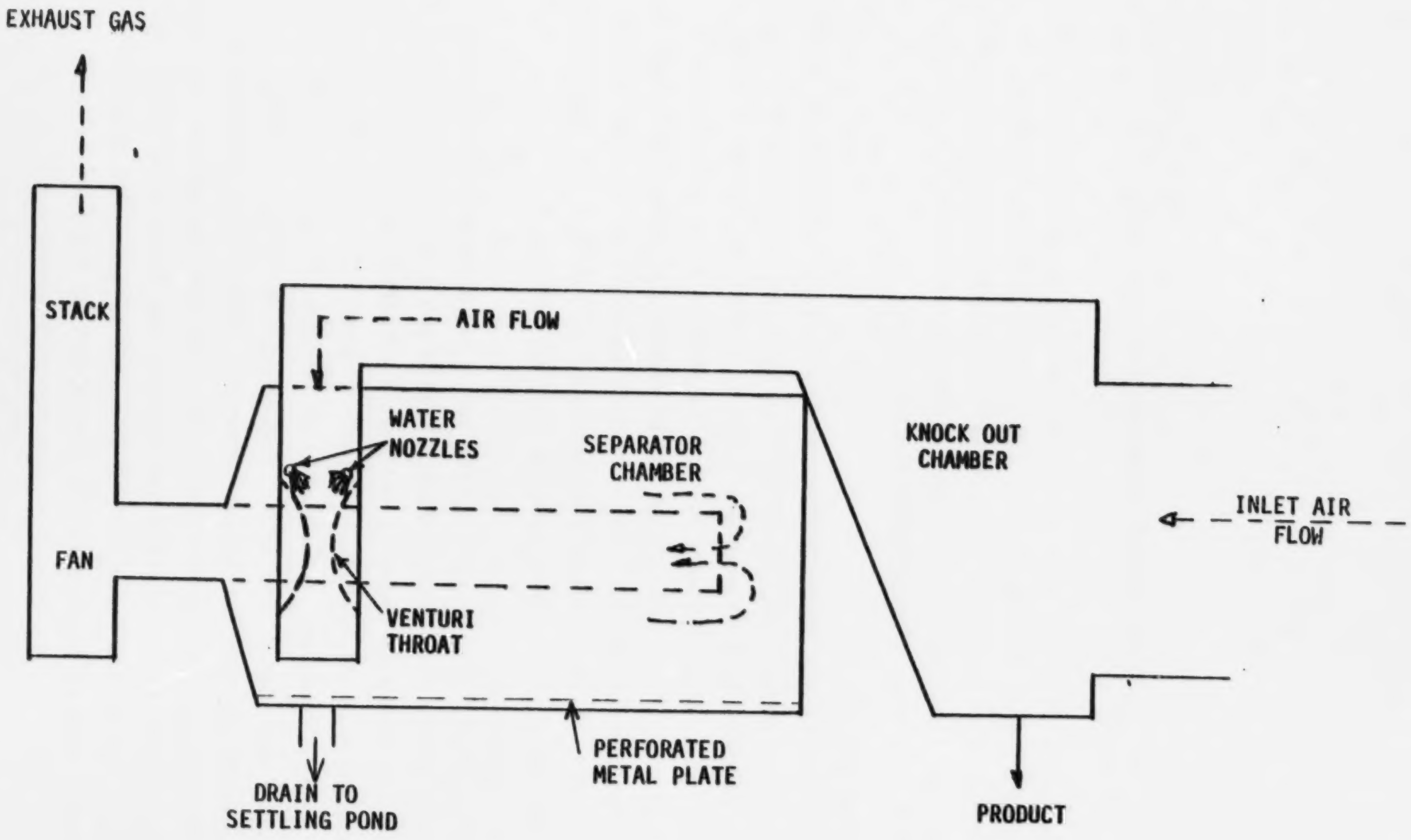

EXHAUST GAS
STACK
FAN
AIR FLOW
WATER NOZZLES
SEPARATOR CHAMBER
KNOCK OUT CHAMBER
INLET AIR FLOW
VENTURI THROAT
PERFORATED METAL PLATE
DRAIN TO SETTLING POND
PRODUCT

Figure 4-1. Venturi scrubber control device on asphalt concrete plant.

matter. Absorption of the condensible hydrocarbons in the water is also possible.

Venturi scrubbers in the asphalt concrete industry have pressure drops that range from 2.5 to 5.2 kilopascals (kPa) (10 to 21 inches of water column [in. w.c.]).[3,4] A typical liquid-to-gas ratio for these scrubbers is 1,070 liters per thousand cubic meters (ℓ/1,000 m^3) (8 gallons per thousand cubic feet [gal/1,000 ft^3]).[5,6]

The solids concentration in the scrubbing water can affect collection efficiency. If scrubbing water is recycled from a settling pond, the water must be sufficiently free of solids to prevent particle reentrainment in the gas stream and particle carryover to the exhaust gas. Reducing solids in the scrubber water also helps reduce abrasion and plugging of scrubber spray nozzles. The settling ponds must, therefore, be constructed to maximize settling of solids present in the scrubber effluent water.

4.1.2 Fabric Filters

Fabric filters have been used successfully as particulate control devices in both batch and drum-mix plants. Of the 45 plants visited to collect background information during this NSPS review, 26 were baghouse-controlled. The fabric used in most baghouses at asphalt concrete plants is composed of felted Nomex®, a nylon that can withstand temperatures up to 232°C (450°F).[7] The typical weight of the fabric is 0.5 kilograms per square meter (14-ounces [weight] per square yard).[4,7-9] The fabric is formed into long cylindrical bags that are fitted over a cylindrical wire form, called a "cage", which supports the fabric bags. Fabric filters on portable asphalt concrete plants are typically no more than 2.4-m (8-ft) wide and 4.3-m (14-ft) high so that they can be transported on public roads.[10]

A fan is located at the outlet of the fabric filter, providing suction, or negative pressure, to draw the gas stream through the fabric filter from the dryer or drum. A pressure drop across the fabric filter bags of 1.0 to 1.6 kPa (4 to 6.5 in. w.c.) is typical. Fabric filters used in the asphalt concrete industry have a typical air-to-cloth ratio (ft^3/min of airflow per ft^2 of cloth area) of 6:1.

Most fabric filters in the asphalt concrete industry use a pulse jet cleaning system.[10,11] In pulse jet systems, compressed air is injected into single bags or groups of bags. The air expands the bag like a balloon and temporarily reverses the direction of the gas flow through the fabric. The reversed gas flow and expansion of the bag cause the dust cake to break from the fabric and fall into a hopper at the bottom of the fabric filter. Typically, screw conveyors move the collected dust from the hoppers to the discharge area where the material is recycled back to the production process.

In the normal startup procedure for asphalt concrete plants, the burner is fired without any aggregate in the drum to increase the temperature of the gas stream above the water dew point but not so hot as to damage the fabric.[12] This procedure prevents moisture in the gas stream from condensing on the bags and causing them to clog or "blind."

The shutdown procedure consists of allowing the baghouse to continue to operate for at least one cleaning cycle after the burner and aggregate feed have been shut down.[13] This procedure removes the dust cake from the bags and prevents moisture from condensing as the baghouse cools.

4.2 ANALYSIS OF NSPS COMPLIANCE TESTS

During the present review of the asphalt concrete NSPS, 369 compliance test reports were collected from State agencies and reviewed.[14] A summary of this review is presented in Table 4-1. It should be noted that, due to the mobile nature of the subject plants, it was often difficult to determine if two test reports for a given company represented two different plants or the same plant that was relocated.

Of the 292 reports in which the control device was identified, 21 percent of the plants used a baghouse, and 79 percent used a scrubber. Of the 327 plants identified as either batch or drum-mix, 49 percent were batch, and 51 percent were drum-mix. Of the 325 plants reporting numerical test results, 13 percent had particulate emissions greater than the NSPS limit of 90 milligrams per dry standard cubic meter (mg/dscm) (0.04 grains per dry standard cubic foot [gr/dscf]). Of these 41 plants, the majority were scrubber-controlled drum-mix plants. The pressure

TABLE 4-1. COMPLIANCE TEST REPORT SUMMARY[14]

		No.	Percent
Total reports collected		369	
Identified control method		292	
Baghouse		(62)	(21)
Scrubber		(230)	(79)
Identified type of plant		327	
Batch		(160)	(49)
Drum-mix		(167)	(51)
Identified test results		325	
Test results failed NSPS limit[a]		(41)	(13)
Batch plant		(4)	(10)
Drum-mix plant		(23)	(56)
Process unidentified		(14)	(34)
Baghouse controlled		(8)	(20)
Scrubber controlled		(25)	(61)
Control method unidentified		(8)	(20)
Scrubber controlled plants identifying ΔP		60	
ΔP <20 in. w.c.		(49)	(82)
Identified both design capacity and production rate during test		150	
Production during test:	100% of capacity	(20)	(13)
	90-99% of capacity	(21)	(14)
	80-89% of capacity	(31)	(21)
	70-79% of capacity	(20)	(13)
	60-69% of capacity	(29)	(19)
	50-59% of capacity	(20)	(13)
	40-49% of capacity	(6)	(4)
	30-39% of capacity	(1)	(1)
	0-29% of capacity	(2)	(2)
Used RAP during test		51	
Drum-mix		(49)	(96)
Batch		(0)	(0)
Process unidentified		(2)	(4)
Baghouse controlled		(23)	(45)
Scrubber controlled		(28)	(55)
Failed NSPS		(9)	(18)
Drum-mix plant		(7)	(78)
Process unidentified		(2)	(22)
Baghouse controlled		(1)	(11)
Scrubber controlled		(8)	(89)

[a] 90 milligrams per dry standard cubic meter (mg/dscm) (0.04 grains per dry standard cubic foot [gr/dscf]).

drop (ΔP) across the scrubber was not monitored during most testing; however, of the 60 plants that did report a ΔP across the scrubber, 82 percent were less than 5 kPa (20 in. w.c.). The ΔP distribution among these 60 plants is illustrated in Figure 4-2. Of the 150 plants reporting both design capacity and production rate during testing, 52 percent were operated below 80 percent of design capacity during testing. This distribution is shown in Table 4-1.

Of the 369 reports collected, 99 reports included opacity information. Of these 99 reports, 31 presented complete opacity data, 58 gave summaries only, and 10 gave time periods for opacity readings but gave no opacity data. Of the 89 reports presenting either complete or summarized opacity data, 7 reports had 6-minute averages greater than 20 percent. Three of these plants were producing conventional mix. These three also reported particulate emissions greater than 90 mg/dscm (0.04 gr/dscf). The remaining four plants with opacity greater than 20 percent were utilizing recycled asphalt pavement (RAP) during testing. Of these four, one had particulate emissions greater than 90 mg/dscm (0.04 gr/dscf), two had particulate emissions less than 90 mg/dscm (0.04 gr/dscf), and one did not report the particulate emission level.

The majority of test reports did not include any information on the type of asphalt concrete being produced or whether RAP was used during testing. Of the 51 reports clearly identifying the use of RAP during testing, 96 percent were drum-mix plants, and 4 percent did not identify the type of process; also, 45 percent were baghouse controlled, and 55 percent were scrubber controlled. Eighteen percent of the plants using RAP during testing had particulate emissions greater than 90 mg/dscm (0.04 gr/dscf). Most of these plants were scrubber-controlled drum-mix plants.

4.3 ANALYSIS OF SITE VISITS

Site visits were conducted to collect general background information on the asphalt concrete industry and to select representative plants for testing. Visits were made to 45 asphalt plants owned by 34 different companies and to 5 equipment manufacturers.[15] Almost all of the plants visited were equipped to utilize RAP. Although some plants reportedly

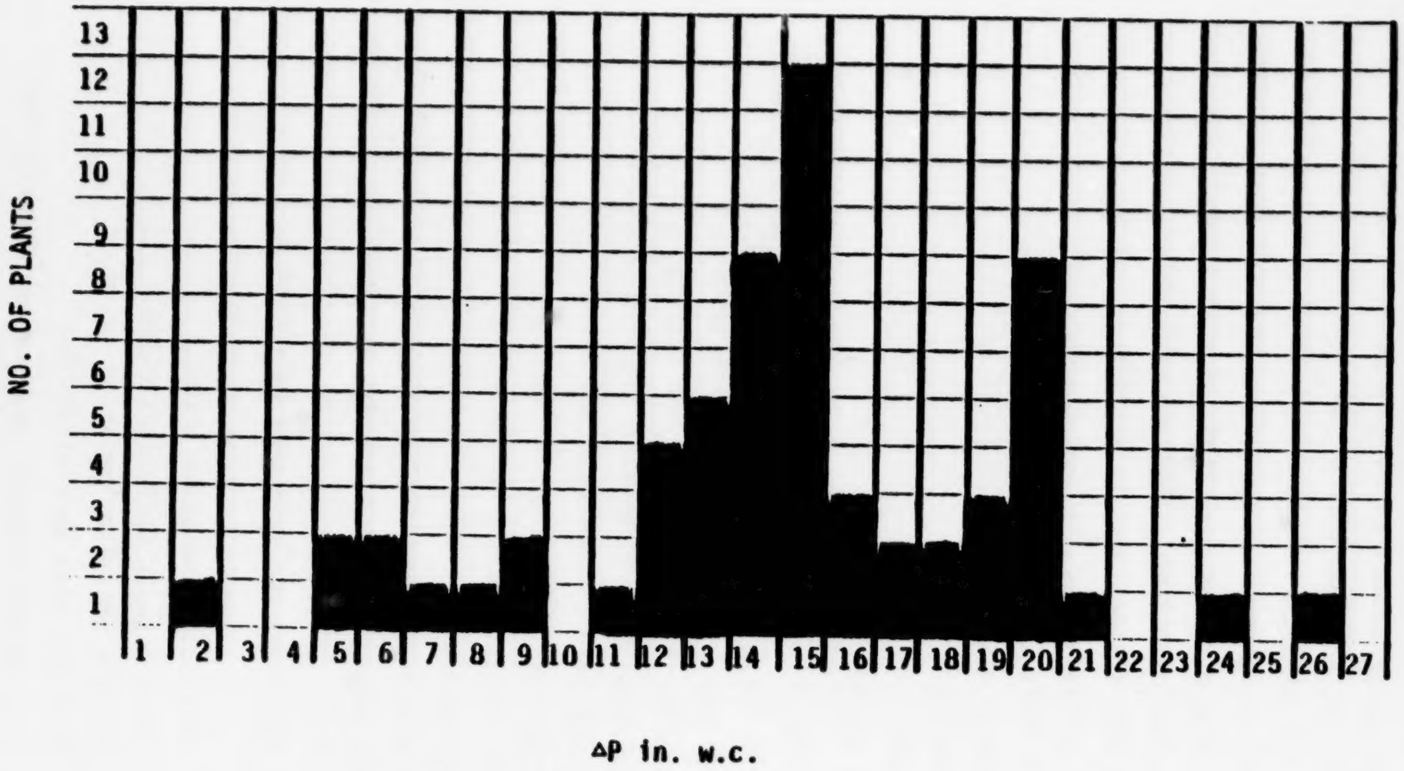


Figure 4-2. ΔP distribution among NSPS compliance tests.

were capable of using up to 66 percent RAP, most did not exceed 50 percent RAP in actual practice. The most common RAP usage range was 25 to 30 percent. Because RAP usage appears to be more common with drum-mix plants than with batch plants and because of the interest in plants utilizing RAP, only 7 of the 45 plants visited were batch plants. Five of the seven batch plants were scrubber-controlled, and two were baghouse-controlled. Of the 38 drum-mix plants visited, 14 were scrubber-controlled, and 24 were baghouse-controlled. Although most venturi scrubbers used at asphalt plants are designed to operate at a 5 kPa (20-in. w.c.) pressure drop (ΔP), it was found that the average normal operating pressure drop is about 4.0 kPa (16 in. w.c.). About 25 percent of the scrubber-controlled plants reporting a ΔP value reported operating their scrubbers at 5 kPa (20 in. w.c.) or more.[15] About half of the plants visited reported blue haze emissions during production of RAP mixes. This blue haze generally developed downwind from the plant.[15]

4.4 ANALYSIS OF EMISSION TESTS CONDUCTED BY EPA DURING NSPS REVIEW

During the NSPS review, tests were conducted by EPA at four asphalt concrete plants.[16] These plants were chosen for testing because their ductwork configurations allowed for testing of both uncontrolled and controlled emissions and because they had predictable production schedules that included both conventional and RAP mixes. The plants were operated above 80 percent of capacity during production of the various mixes. The control device and the amount of RAP used at Plants A, B, C, and D are presented in Table 4-2. Plant design and operating parameters at the four plants are presented in Table 4-3. Scrubber and baghouse design and operating parameters are presented in Tables 4-4 and 4-5, respectively.

The following analyses were performed at some or all of the test sites:

1. Particulate emission level;
2. Total organic carbon/extractable organic emission level;
3. Visible emission level;
4. Particle size determinations;
5. Polynuclear aromatic hydrocarbon emission level; and
6. Trace metals concentration.

TABLE 4-2. CONTROL DEVICE AND RAP UTILIZATION[16]

Plant	Control device	Mix produced
A	Venturi scrubber	Conventional and 25 percent RAP
B	Venturi scrubber	50 percent RAP
C	Baghouse	Conventional and 30 percent RAP
D	Baghouse	Conventional and 50 percent RAP

TABLE 4-3. PLANT DESIGN AND OPERATING PARAMETERS[16]

Plant	A	B	C	D
Type	Drum-mix	Drum-mix	Drum-mix	Drum-mix
Capacity, Mg/h (tons/h)				
Rated	218 (240)[17]	229 (252)	386 (425)	390 (430)
Typical	218 (240)	181 (200)	272 (300)	272-318 (300-350)
During test	214 (236)	181 (200)	218 to 308[a] (240-340)[a]	279 (307)
Dryer fuel	Natural gas	No. 5 fuel oil	Natural gas	No. 5 fuel oil
Approximate drum size, m (ft)				
Diameter	2.4 (8)	2.1 (7)	2.7 (9)	2.7 (9)
Length	11 (36)	13 (42)	12 (38)	12 (40)
Product temperature, °C (°F)	135-163 (275-325)	135-149 (275-300)	154 (310)	135-143 (275-290)
RAP entry position	Centerfeed	Centerfeed	Centerfeed	Centerfeed
Asphalt cement				
Conventional	AC-20	--	AC-20	85-100 penetration
RAP	AC-7.5	HMA-175	AC-10	120-150 penetration

[a] Average production rate during 30 percent RAP mix was 308 Mg/h (340 tons/h); during conventional mix was 218 Mg/h (240 tons/h).

TABLE 4-4. SCRUBBER DESIGN AND OPERATING PARAMETERS[16]

	A	B
Type	Venturi scrubber	Venturi scrubber
Total airflow, m^3/min (acfm)		
Design	991-1,020 (35,000-36,000)	1,220 (43,000)
During test	825 (29,080)	1,030 (36,500)
Water circulation rate, ℓ/min (gpm)		
Design	1,140 (300)	1,140-1,510 (300-400)
During test	828 (220)	1,368 (362)
Make-up water source	Groundwater, as needed	Groundwater
ΔP, design, kPa (in. w.c.)[18,19]	13.5-15.5	20
ΔP across venturi during test, kPa (in. w.c.)	3.1-3.6 (12.5-14.5)	4.3-5.0 (17-20)
Liquid/gas ratio, ℓ/m^3 (gal/1,000 acf)		
Design	1.1-1.2 (8.3-8.6)	0.93-1.2 (7.0-9.3)
During test	1.0 (7.6)	1.3 (9.9)
Ponds:		
No.	2	2
Size, m (ft)		
Length	17, 20 (55, 65)	18, 18 (60, 60)
Width	7.3, 7.3 (24, 24)	5.5, 7.3 (18, 24)
Depth	0.9-1.8, 0.9-1.8 (3-6, 3-6)	1.5, 1.5 (5, 5)
Total volume, 1,000 ℓ (1,000 gal)	246-492 (65-130)	358 (94.5)
Residence time, h	3.6-7.2	3.9-5.2

m^3/min = actual cubic meter per minute
acfm = actual cubic feet per minute
ℓ/min = liter per minute
gpm = gallon per minute
kPa = kilopascal
in. w.c. = inches of water column

TABLE 4-5. BAGHOUSE DESIGN AND OPERATING PARAMETERS[16]

	C	D
Type	Negative pressure baghouse	Negative pressure baghouse
Total airflow rate, m^3/min (acfm)		
Design	1,470 (52,000)	1,590 (56,000)
During test	1,320 (46,670)	1,200 (42,200)
No. of bags	462	900
Bag material	Nomex	Nomex
Normal pressure drop, kPa (in. w.c.)	1 (4)	1.3 (5)
Bag cleaning mechanism	Pulse jet	Pulse jet
Air-to-cloth ratio,		
Design	~7:1	6.3:1
During test	~6.3:1	4.8:1
Dust disposal	Recycled to drum	Recycled to drum

In addition, selected physical characteristics were determined for samples of RAP, asphalt cement, aggregate, and scrubber water.

4.4.1 Particulate Emissions (Front-Half Catch)

The uncontrolled and controlled particulate emission levels during production of conventional and RAP mixes at the four representative plant sites are presented in Table 4-6. The corresponding process parameters are presented in Table 4-7.

For conventional mixes, the uncontrolled particulate emissions ranged from 12,600 mg/dscm to 253,000 mg/dscm (5.58 to 112.66 gr/dscf). The uncontrolled particulate emissions were generally lower during production of RAP mixes than during production of conventional mixes. For RAP mixes, the uncontrolled particulate emissions ranged from 7,290 mg/dscm to 24,600 mg/dscm (3.24 to 10.93 gr/dscf).

The controlled particulate emissions during production of conventional mixes at Plants A and C and the controlled particulate emissions during production of RAP mix at Plant B exceeded the NSPS limit of 90 mg/dscm (0.04 gr/dscf). The NSPS limit is based on emission data that are representative of the performance of a 5 kPa (20 in. w.c.) pressure drop venturi scrubber. The pressure drop across the venturi at Plant A averaged between 3.3 and 3.4 kPa (13.4 and 13.5 in. w.c.) during production of conventional mix. This lower pressure drop contributed to the plant's failure to meet the NSPS while producing conventional mixes. Due to the low uncontrolled emission level during production of RAP mix, the scrubber met the NSPS despite its low pressure drop.

The pressure drop across the venturi at Plant B averaged between 4.2 and 5 kPa (17 and 20 in. w.c.) during testing. During one period, the pressure drop across the venturi dropped to 3.2 kPa (13 in. w.c.). The dissolved solids concentration in the scrubber water at Plant B was approximately seven times the dissolved solids concentration observed at Plant A. The high dissolved solids level and low pressure drop contributed to the failure of Plant B to meet the present NSPS.

After test Run C-1 at Plant C, problems were encountered with the operation of the plant that resulted in blinding of the bags and a pressure drop across the baghouse of greater than 2.5 kPa (10 in. w.c.). Although the bags were subsequently cleaned and the average pressure

TABLE 4-6. SUMMARY OF EMISSION DATA FROM EPA-CONDUCTED TESTS

		Production data			Emissions data							
					Inlet-uncontrolled			Outlet-controlled				
Plant	Run No.	Total production, Mg/h (tons/h)	RAP, %	Mix temp., °C (°F)	Dry catch, mg/dscm (gr/dscf)	TOC, mg/dscm (gr/dscf)	Film, mg/dscm (gr/dscf)	Dry catch, mg/dscm (gr/dscf)	TOC, mg/dscm (gr/dscf)	Film, mg/dscm (gr/dscf)	Avg. opacity, %	Max. 6-min opacity, %
A	C-1	220 (243)	0	142 (288)	17,400 (7.60)	a	396 (0.173)	126 (0.055)	a	128 (0.056)	0	1.5
A	C-2	213 (235)	0	136 (277)	19,400 (8.49)	a	105 (0.046)	185 (0.081)	a	32 (0.014)	0	0
A	C-3	179 (218)	0	143 (289)	12,800 (5.58)	a	261 (0.114)	76 (0.033)	a	21 (0.009)	NA	NA
A	R-1	207 (228)	25	146 (295)	7,410 (3.24)	a	311 (0.136)	52 (0.023)	a	25 (0.011)	1.4	5.8
A	R-2	229 (252)	24	135 (275)	10,000 (4.37)	a	304 (0.133)	53 (0.023)	a	71 (0.031)	0.3	1.7
A	R-3	219 (241)	25	141 (286)	8,580 (3.75)	a	142 (0.062)	66 (0.029)	a	39 (0.017)	NA	NA
B	R-1	188 (207)	51	142 (288)	18,500 (8.09)	799 (0.349)	b	263 (0.115)	53 (0.023)	b	8.4	11.9
B	R-2	172 (190)	51	143 (290)	12,700 (5.54)	117 (0.051)	b	297 (0.130)	57 (0.025)	b	13.6	17.5
B	R-3	178 (196)	51	143 (290)	14,100 (6.15)	124 (0.054)	b	327 (0.143)	57 (0.025)	b	12.3	16.9
B	R-4	185 (204)	51	140 (284)	12,100 (5.28)	119 (0.052)	b	259 (0.113)	43 (0.019)	b	9.8	12.9
C	C-1	216 (238)	0	159 (319)	43,500 (19.01)	a	69 (0.030)	25 (0.011)	a	32 (0.014)	c	c
C	C-2	218 (240)	0	165 (329)	34,400 (15.05)	a	82 (0.036)	297 (0.130)	a	62 (0.027)	c	c
C	C-3	218 (240)	0	162 (323)	38,200 (16.70)	a	89 (0.039)	2,950 (1.29)	a	96 (0.042)	c	c

(continued)

TABLE 4-6. (continued)

		Production data			Emissions data							
					Inlet-uncontrolled			Outlet-controlled				
Plant	Run No.	Total production, Mg/h (tons/h)	RAP, %	Mix temp., °C (°F)	Dry catch, mg/dscm (gr/dscf)	TOC, mg/dscm (gr/dscf)	Film, mg/dscm (gr/dscf)	Dry catch, mg/dscm (gr/dscf)	TOC, mg/dscm (gr/dscf)	Film, mg/dscm (gr/dscf)	Avg. opacity, %	Max. 6-min opacity, %
C	R-1	316 (348)	27	157 (315)	12,700 (5.54)	a	80 (0.035)	41 (0.018)	a	NA	c	c
C	R-2	308 (339)	29	156 (312)	16,000 (7.00)	a	64 (0.028)	76 (0.033)	a	137 (0.060)	c	c
C	R-3	307 (338)	28	161 (321)	15,600 (6.82)	a	66 (0.029)	34 (0.015)	a	14 (0.006)	c	c
D	C-1	281 (310)	0	153 (307)	106,000 (46.33)	NA	71 (0.031)	18 (0.008)	41 (0.018)	23 (0.010)	NA	NA
D	C-2	282 (311)	0	152 (305)	258,000 (112.66)	105 (0.046)	108 (0.047)	57 (0.025)	41 (0.018)	50 (0.022)	0.25	1.3
D	C-3	277 (305)	0	149 (300)	201,000 (87.84)	39 (0.017)	57 (0.025)	64 (0.028)	37 (0.016)	23 (0.010)	NA	NA
D	C-4	244 (269)	0	149 (301)	123,000 (53.50)	96 (0.042)	606 (0.265)	50 (0.022)	37 (0.016)	18 (0.008)	NA	NA
D	R-1	301 (332)	49	143 (290)	16,200 (7.08)	64 (0.028)	37 (0.016)	18 (0.008)	137 (0.060)	105 (0.046)	4.5	5
D	R-2	281 (310)	49	143 (290)	25,000 (10.93)	240 (0.105)	85 (0.037)	14 (0.006)	117 (0.051)	34 (0.015)	NA	NA
D	R-3	281 (310)	49	143 (290)	19,800 (8.66)	80 (0.035)	220 (0.096)				NA	NA

NA = Not available.

[a] TOC data and total emission data are not included for Plants A and C due to problems with TOC testing methodology and analytical procedures.
[b] No film was collected at Plant B.
[c] The opacity readings from Plant C are not included due to technical problems experienced with the reading of opacity at this plant.

TABLE 4-7. SUMMARY OF PROCESS PARAMETERS FROM EPA-CONDUCTED TESTS[16]

		Production data						Scrubber data--influent					
Plant	Run No.	Total production, Mg/h (tons/h)	RAP, %	Mix temp., °C (°F)	Virgin moisture, %	RAP moisture, %	RAP smoke point, °C (°F)	Pressure drop, kPa (in. w.c.)	Suspended solids, mg/ℓ	Dissolved solids, mg/ℓ	pH	Liquid to gas, gal/scf	Water temp., °C (°F)
A	C-1	220 (243)	0	142 (288)	2.7	--	--	3.36 (13.5)	161	1,860	7.3	0.019	56 (132)
A	C-2	213 (235)	0	136 (277)	2.3	--	--	2.33 (13.4)	24	1,780	7.3		52 (126)
A	C-3	179 (218)	0	143 (289)	2.6	--	--	3.36 (13.5)	124	1,770	7.4	0.017	48 (118)
A	R-1	207 (228)	25	146 (295)	1.5	1.5	179 (355)	3.44 (13.8)	78	1,960	7.3	0.015	43 (109)
A	R-2	229 (252)	24	135 (275)	1.8	1.4	--	3.44 (13.8)	144	1,970	7.3	0.018	55 (131)
A	R-3	219 (241)	25	141 (286)	1.2	2.1	--	3.46 (13.9)	179	1,890	7.4	0.016	43 (110)
B	R-1	188 (207)	51	142 (288)	4.1	2.6	179 (355)	4.48 (18)	57	14,700	6.2	0.021	58 (137)
B	R-2	172 (190)	51	143 (290)	5.9	1.6	179 (355)	4.23 (17)	18	12,100	6.1	0.020	51 (124)
B	R-3	178 (196)	51	143 (290)	6.4	1.9	180 (356)	4.98 (20)	34	13,000	6.1	0.021	59 (138)
B	R-4	185 (204)	51	140 (284)	5.7	1.8	177 (350)	4.98 (20)	49	13,800	6.1	0.022	60 (140)
C	C-1	216 (238)	0	159 (319)	3.3	--	--	1.1 (4.3)[a]				5.6[b]	
C	C-2	218 (240)	0	165 (329)	3.8	--	--	1.3 (5.1)[a]				5.6[b]	
C	C-3	218 (240)	0	162 (323)	3.4	--	--	1.5 (5.9)[a]				5.6[b]	

(continued)

TABLE 4-7. (continued)

		Production data						Scrubber data--influent					
Plant	Run No.	Total production, Mg/h (tons/h)	RAP, %	Mix temp., °C (°F)	Virgin moisture, %	RAP moisture, %	RAP smoke point, °C (°F)	Pressure drop, kPa (in. w.c.)	Suspended solids, mg/ℓ	Dissolved solids, mg/ℓ	pH	Liquid to gas, gal/scf	Water temp., °C (°F)
C	R-1	316 (348)	27	157 (315)	3.4	NA	99 (211)	1.0 (4.0)[a]				5.6[b]	
C	R-2	308 (339)	29	156 (312)	5.7	3.2	98 (209)	1.0 (4.0)[a]				5.6[b]	
C	R-3	307 (338)	28	161 (321)	3.2	5.1	100 (212)	1.0 (4.0)[a]				5.6[b]	
D	C-1	281 (310)	0	153 (307)	2.1	--	--	1.4 (5.5)[a]				6.3[b]	
D	C-2	282 (311)	0	152 (305)	2.0	--	--	1.4 (5.6)[a]				6.3[b]	
D	C-3	277 (305)	0	149 (300)	2.3	--	--	1.4 (5.6)[a]				6.3[b]	
D	C-4	244 (269)	0	149 (301)	3.2	--	--	1.2 (5.0)[a]				6.3[b]	
D	R-1	301 (332)	49	143 (290)	4.8	2.0	173 (344)	1.1 (4.3)[a]				6.3[b]	
D	R-2	281 (310)	49	143 (290)	1.7	4.1	182 (360)	1.2 (4.7)[a]				6.3[b]	
D	R-3	281 (310)	49	143 (290)	1.7	4.1	182 (360)	1.2 (4.7)[a]				6.3[b]	

[a] Baghouse pressure drop.

[b] Baghouse air-to-cloth ratio, acfm/ft², design.

drop across the baghouse was 1.3 and 1.5 kPa (5.1 and 5.9 in. w.c.) for Runs C-2 and C-3, respectively, the previous blinding and high pressure drop apparently created leaks in the bags and caused Plant C not to meet the NSPS during Runs C-2 and C-3. Runs R-1, R-2, and R-3 at Plant C were performed prior to this blinding.

Because of the lower uncontrolled particulate emission levels during production of RAP mixes, the controlled particulate emission levels at Plants A and D were lower during production of RAP mixes than during production of conventional mixes. Only RAP mixes were produced at Plant B, and problems with the baghouse were experienced at Plant C, as already discussed.

4.4.2 Total Organic Carbon

The total organic carbon (TOC) emission results are presented in Table 4-6. Due to problems with TOC testing methodology and analytical procedures (as discussed in Appendix C), TOC data for Plants A and C are not included.

An organic film was collected from the impinger walls during the TOC tests at Plants A and C. Since this film is measured gravimetrically and TOC is a measure of carbon present as a constituent of organic compounds, the two results cannot be added directly.

The uncontrolled and controlled emission level of the material comprising this film ranged from 105 to 396 mg/dscm (0.046 to 0.173 gr/dscf) and from 21 to 128 mg/dscm (0.009 to 0.056 gr/dscf), respectively, during production of conventional mix at Plant A. During production of RAP mix at Plant A, the uncontrolled and controlled emission level of the material comprising the film ranged from 142 to 311 mg/dscm (0.062 to 0.136 gr/dscf) and 25 to 71 mg/dscm (0.011 to 0.031 gr/dscf), respectively.

During production of conventional mix at Plant C, the uncontrolled and controlled emission level of the material comprising the film ranged from 69 to 89 mg/dscm (0.030 to 0.039 gr/dscf) and 32 to 96 mg/dscm (0.014 to 0.042 gr/dscf), respectively. During production of RAP mix at Plant C, the uncontrolled and controlled emission level of the material comprising the film ranged from 64 to 80 mg/dscm (0.028 to 0.035 gr/dscf), and 14 to 134 mg/dscm (0.006 to 0.060 gr/dscf), respectively.

The uncontrolled TOC emissions at Plant B ranged from 117 to 799 mg/dscm (0.05 to 0.349 gr/dscf) during production of RAP mixes and the controlled TOC emissions ranged from 43 to 57 mg/dscm (0.019 to 0.025 gr/dscf). No film was observed on the TOC impinger walls during testing at Plant B.

During production of conventional mixes at Plant D, the uncontrolled TOC emissions ranged from 39 to 105 mg/dscm (0.017 to 0.046 gr/dscf), and the controlled TOC emissions ranged from 37 to 41 mg/dscm (0.016 to 0.018 gr/dscf). During production of RAP mixes at Plant D, the uncontrolled TOC emissions ranged from 64 to 240 mg/dscm (0.028 to 0.105 gr/dscf) and the controlled TOC emissions ranged frm 117 to 137 mg/dscm (0.051 to 0.060 gr/dscf).

A film was observed on the TOC impinger walls during testing at Plant D. During production of conventional mixes at Plant D, the uncontrolled and controlled emission level of the material comprising this film ranged from 71 to 606 mg/dscm (0.031 to 0.265 gr/dscf) and 18 to 50 mg/dscm (0.008 to 0.022 gr/dscf), respectively. During production of RAP mixes at Plant D, the uncontrolled and controlled emission level of the material comprising this film ranged from 37 to 220 mg/dscm (0.016 to 0.096 gr/dscf) and 34 to 105 mg/dscm (0.015 to 0.04 gr/dscf), respectively.

Based on the results of EPA-conducted source tests, the only correlation that can be drawn is that TOC emissions are approximately equal during production of RAP and conventional mixes.

4.4.3 Visible Emissions

The test average and maximum 6-minute average opacity readings for emission tests performed during production of both conventional and RAP mixes at Plants A, B, and D are presented in Table 4-6. The test average and maximum 6-minute average opacity readings at Plant A ranged from 0.3 to 1.4 and 1.5 to 5.8, respectively. At Plant B, the test average and maximum 6-minute average opacity readings ranged from 8.4 to 13.6 and 11.9 to 17.5, respectively. Ranges of 0.25 to 4.5 and 1.3 to 5 were observed for the test average and maximum 6-minute average opacity readings, respectively, at Plant D. No readings were made during some test runs due to overcast skies.

Field data sheets from Plant C indicate that some or all of the opacity readings at Plant C were made within the steam plume instead of in the areas specified by EPA Reference Method 9. For this reason, opacity readings are not given in Table 4-6 for Plant C.

The visible emission data for the scrubber and baghouse control systems should not be compared. The baghouse data from Plant D were obtained from observations made at the stack outlet, prior to the stack gases condensing and becoming visible. In contrast, an attached steam plume was present at the exhaust stack of the wet scrubber at Plants A and B. As specified in Method 9, the observations reported for Plants A and B were made at a point in the emissions plume where the condensed water vapor was no longer visible. Because of the steam plume, the scrubber data at Plants A and B were obtained from observations made 24 to 61 m (80 to 200 ft) downstream from the stack.

4.4.4 Particle Size Determinations

The results of the particle size analyses on uncontrolled emission streams at Plants A and B are presented in Figure 4-3. In general, the particles emitted during production of RAP mixes are larger than those emitted during production of conventional mixes. For the three runs conducted during RAP production, the results show that between 15 and 30 percent of the total mass of particulate matter is less than 10 micrometers (μm) in diameter. For the three runs conducted during production of conventional mix, the particle size distribution measurements show that between 45 and 60 percent of the total particulate mass is less than 10 μm in diameter.

The particle size distribution tests conducted at Plant C were all outside the accepted isokinetic range. Therefore, these data were discarded.

No particle size distribution tests were conducted at Plant D due to curtailed process operations.

4.4.5 Polynuclear Aromatic Hydrocarbons

A summary of the uncontrolled and controlled polynuclear aromatic hydrocarbon (PAH) emissions during conventional operation at Plant A is presented in Table 4-8. Table 4-9 presents a summary of uncontrolled and controlled PAH emissions during recycle operations at Plant A.

TABLE 4-8. SUMMARY OF POLYNUCLEAR AROMATIC HYDROCARBON EMISSIONS DURING CONVENTIONAL OPERATION--PLANT A[16]

Process/testing parameters	Uncontrolled	Controlled
Date	11/14/83	11/14/83
Volume gas sampled, dscm (dscf)	0.3472 (12.3)	1.1963 (42.4)
Stack gas flow rate, m^3/min (dscfm)	289 (10,200)	331 (11,700)
Stack temperature, °C (°F)	156 (313)	70 (158)
Scrubber pressure drop, in. w.c.	13.4	13.4
Scrubber water flow rate, gpm	220	220
Percent moisture by volume	42.2	32.2
Percent isokinetic	111	103
Production rate, tons/h	196	196

CONCENTRATIONS AND MASS EMISSION RATES

Polynuclear aromatic hydrocarbon results	Uncontrolled total (μg/dscm)	Uncontrolled total (mg/h)	Controlled total (μg/dscm)	Controlled total (mg/h)
Active carcinogenic species[a]				
Benz(a)anthracene	1.4	24	0.22	4.4
Chrysene	7.3	130	1.2	24
Benzo(b)fluoranthene	0.58	10	0.50	9.9
Benzo(j)fluoranthene	ND[b]		ND	
Benzo(e)pyrene	3.5	61	0.17	3.4
Benzo(a)pyrene	1.4	24	ND	
Indeno(1,2,3-c,d)-pyrene	1.7	29	0.084	1.7
Nonactive carcinogenic species				
Phenanthrene	140	2,400	100	2,000
Anthracene	20	350	7.1	140
Fluoranthene	13	230	2.5	56
Pyrene	36	620	6.4	150
Benzo(k)fluoranthene	0.58	10	0.50	9.9
Perylene	0.58	10	0.17	3.4
Benzo(g,h,i)perylene	ND		ND	

[a] Futoma, David, et al. Polycyclic Aromatic Hydrocarbons in Water Systems. Boca Raton, Fla., CRC Press, Inc., 1981. Reference used to determine if PNA species were active or nonactive carcinogens.

[b] ND = not detected.

TABLE 4-9. SUMMARY OF POLYNUCLEAR AROMATIC HYDROCARBON EMISSIONS DURING RECYCLE OPERATION--PLANT A[16]

Process/testing parameters	Uncontrolled	Controlled
Date	11/15/83	11/15/83
Volume gas sampled, dscm (dscf)	0.4590 (16.2)	1.2789 (45.2)
Stack gas flow rate, m^3/min, (dscfm)	294 (10,400)	280 (9,900)
Stack temperature, °C (°F)	148 (299)	78 (173)
Scrubber pressure drop, in. w.c.	12.7	12.7
Scrubber water flow rate, gpm	214	214
Percent moisture by volume	48.0	43.4
Percent isokinetic	105	113
Production rate, tons/h	166	166

CONCENTRATIONS AND MASS EMISSION RATES

Polynuclear aromatic hydrocarbon results	Uncontrolled total		Controlled total	
	(µg/dscm)	(mg/h)	(µg/dscm)	(mg/h)
Active carcinogenic species[a]				
Benz(a)anthracene	1.8	32	0.75	13
Chrysene	8.4	150	2.6	44
Benzo(b)fluoranthene	0.087	1.5	0.24	4.0
Benzo(j)fluoranthene	ND		ND	
Benzo(e)pyrene	1.9	34	0.55	9.2
Benzo(a)pyrene	0.50	8.8	0.31	5.2
Indeno(1,2,3-c,d)-pyrene	0.15	2.6	0.31	5.2
Nonactive carcinogenic species				
Phenanthrene	220	3,900	87	1,500
Anthracene	16	280	18	300
Fluoranthene	20	350	13	220
Pyrene	36	640	26	440
Benzo(k)fluoranthene	0.11	1.9	0.24	4.0
Perylene	0.33	5.8	0.16	2.7
Benzo(g,h,i)perylene	ND		ND	

ND = Not detected.

[a] Futoma, David, et al. Polycyclic Aromatic Hydrocarbons in Water Systems. Boca Raton, Fla., CRC Press, Inc., 1981. Reference used to determine if PNA species were active or nonactive carcinogens.

Polynuclear aromatic hydrocarbon tests were conducted during the emission tests at Plant B; however, the two air samples for PAH were lost during the analysis because of a condenser problem. Scrubber water samples were analyzed for PAH, and the results are summarized in Section 4.4.8.

4.4.6 Trace Metals

A set of air emission samples (uncontrolled and controlled) as well as a set of scrubber water samples (influent and effluent) were analyzed for trace metals at Plant A. The results of the air trace metal emission tests are presented in Tables 4-10 and 4-11 for conventional and RAP operation, respectively. The scrubber water analysis results are presented in Section 4.4.8.

During both conventional and recycle operations, the uncontrolled and controlled concentrations of calcium, iron, magnesium, and aluminum comprised more than 99 percent of the trace metals analyzed in the samples.

Several "more volatile" elements were also detected in the trace metal samples. These elements included beryllium and cadmium. Because of their volatility, a greater percentage of these elements was found in the back half portion of the trace metal sample than was found of the above mentioned nonvolatile elements.

Trace metals were not measured at any of the remaining sites.

4.4.7 RAP, Asphalt Cement, and Aggregate Analyses

The moisture content data for the aggregate and RAP at the four test sites are presented in Table 4-7. The virgin aggregate moisture content ranged from 1.2 to 6.4 percent. The moisture content of the RAP ranged from 1.4 to 5.1 percent.

Samples of RAP and asphalt cement were collected during each run and analyzed for smoke point. The flash point was also determined for the asphalt cement. The results of these tests are presented in Table 4-12.

The asphalt cement used at Plant B was rated by its manufacturer to be HMA-175. This is an asphalt in which the oils that are blended in to adjust the viscosity are generally heavier than those used in other asphalt cements. HMA-grading and AC-grading are not compatible; therefore,

TABLE 4-10. SUMMARY OF TRACE METAL EMISSIONS DURING CONVENTIONAL OPERATION--PLANT A

Samples	Uncontrolled				Controlled			
Production rate, tons/h	244				244			
Trace metal	Mass front half, μg	Mass back half, μg	Mass total, μg	Concentration, μg/dscm	Mass front half, μg	Mass back half, μg	Mass total, μg	Concentration, μg/dscm
Element								
Aluminum	29,500	66	29,600	55,000	453	98	551	404
Beryllium	2.33	0.90	3.23	6.0	0.187	2.6	2.8	2.0
Calcium	2,654,000	1,260	2,660,000	4,930,000	41,000	1,283	42,300	31,000
Cadmium	14.7	5.4	20.1	37	28	13	41	30
Chromium	138	1.47	138	255	7.2	12	19	14
Iron	57,700	53	57,800	107,000	650	61	711	521
Mercury	<273	<20	<293	<544	<90	<56	<146	<107
Magnesium	42,900	50	43,000	79,600	1,234	230	1,460	1,070
Manganese	911	1.8	913	1,700	42.7	5.1	48	35
Nickel	104	<4.4	104	193	16.4	<5.6	16	12
Lead	118	<118	118	219	4.7	<152	4.7	3.4
Vanadium	<540	<88	<628	<1,170	<115	<113	<228	<167
Zinc	194	13	207	385	42.2	9.6	52	38

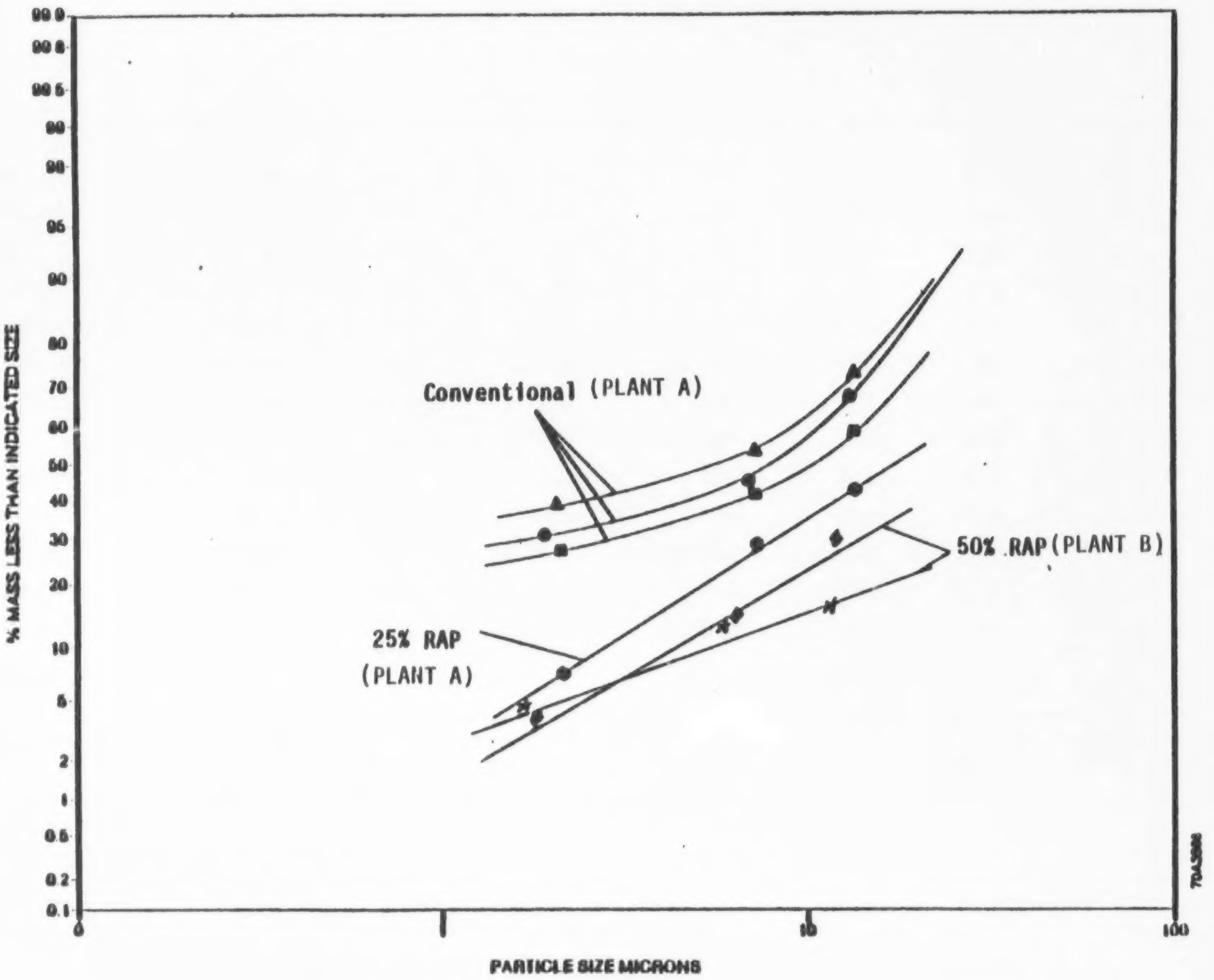


Figure 4-3. Particle size distribution curves of uncontrolled emissions collected during recycle and conventional operation.[16]

TABLE 4-11. SUMMARY OF TRACE METAL EMISSIONS DURING RECYCLE OPERATION--PLANT A

Samples	------------- Uncontrolled			-----------------	------------ Controlled			--------------
Production rate, tons/h	------------------ 244			--------------------	---------------- 244			-----------------
Trace metal	Mass front half, µg	Mass back half, µg	Mass total, µg	Concentration, µg/dscm	Mass front half, µg	Mass back half, µg	Mass total, µg	Concentration, µg/dscm
Element								
Aluminum	13,300	69	13,300	22,500	201	<70	201	124
Beryllium	0.91	1.37	2.28	3.9	0.22	<0.70	0.22	0.14
Calcium	1,154,000	751	1,150,000	1,960,000	18,400	730	19,100	11,800
Cadmium	13.7	6.6	20.3	34	5.8	<2.8	5.8	3.6
Chromium	111	6.25	117	199	8.4	<1.4	8.4	5.2
Iron	26,600	64	24,600	41,800	320	9.8	330	204
Mercury	<136	<40	<176	<298	<60	<41	<101	<62
Magnesium	22,600	121	22,700	38,500	500	<47	500	309
Manganese	362.3	3.2	366	620	18.1	<1.4	18.1	11
Nickel	63.6	2.8	66	112	12	4.8	16.8	10
Lead	89	<113	89	150	4.2	<118	4.2	2.6
Vanadium	<141	<82	<223	<378	<120	<84	<204	<126
Zinc	230	14	244	414	67.3	7.6	74.9	46

TABLE 4-12. RAP AND ASPHALT CEMENT DATA[16]

Plant	Type mix	Smoke point, °C (°F)		Flash point, °C (°F)	AC grade
		RAP	AC	AC	
A	Conventional	--	216 (420)	338 (640)	AC-20
	RAP	179 (355)	174 (345)	288 (550)	
B	RAP	179 (354)	182 (360)	304 (580)	HMA-175
C	Conventional	--	N/A	N/A	AC-20
	RAP	99 (211)	N/A	279 (534)	AC-10
D	Conventional	--	N/A	244 (471)	Penetration 85-100
	RAP	179 (355)	N/A[a]	218 (424)	Penetration 120-150

N/A = Not available.

the asphalt cement used at Plant B cannot be readily compared to those used at the other plants. No viscosity tests were performed on this asphalt cement.

The asphalt cements used at Plant D are rated based on penetration grade instead of AC grade. The viscosities of these asphalt cements were found to be 1,153 poise and 876 poise at 60°C (140°F) for the asphalt cements used with conventional and RAP mixes, respectively. Both these viscosities fall within the 1,000 ± 200 poise range specified for AC-10 by the Asphalt Institute.

The smoke point of the RAP at three of the test sites was approximately 179°C (355°F). The smoke point at the fourth test site was about 99°C (211°F).

The smoke points of the asphalt cements ranged from 174°C to 216°C (345°F to 420°F), and the flash points ranged from 218°C to 338°C (424°F to 640°F). In general, both the smoke point and the flash point were lower for the softer asphalt cements used with RAP mixes than for the asphalt cements used in conventional mixes.

4.4.8 Scrubber Water Analyses

During each sampling run, at least two scrubber influent and effluent water samples were collected. The grab samples from each run were composited and then filtered to determine total suspended solids. An aliquot of the filtrate was analyzed for dissolved solids. The remaining filtrate was analyzed for TOC, trace metals, and/or PAH. The average dissolved solids, suspended solids, pH, and temperatures for the scrubber water samples taken at Plants A and B are presented in Table 4-13.

Analytical problems were encountered with the scrubber water TOC sample from Plant A, and these results are not reported. The TOC results for the venturi scrubber influent and effluent water samples during production of RAP mixes at Plant B are 968 and 985 milligrams per liter (mg/ℓ) (968 and 985 parts per million [ppm]), respectively.

The scrubber water PAH analysis is presented in Table 4-14 for conventional and RAP mix test runs at Plant A. Polynuclear aromatic hydrocarbons were found in trace amounts in the scrubber water during both conventional and RAP operation.

TABLE 4-13. AVERAGE SCRUBBER WATER ANALYTICAL MEASUREMENTS--
PLANTS A AND B[16]

	Dissolved solids, mg/ℓ (ppm)	Suspended solids, mg/ℓ (ppm)	pH	Temp., °C (°F)
Conventional venturi influent				
Plant A	1,800	70	7.3	51 (124)
Conventional venturi effluent				
Plant A	1,800	5,920	7.2	67 (153)
Recycle venturi influent				
Plant A	1,920	115	7.4	48 (119)
Plant B	13,600	53	6.1	57 (135)
Recycle venturi effluent				
Plant A	1,910	2,980	7.2	67 (152)
Plant B	13,800	1,122	5.8	68 (155)

ppm = parts per million.

TABLE 4-14. SCRUBBER WATER PAH ANALYSIS--PLANT A[16]

Polynuclear hydrocarbon	Conventional mix Run No. PAH C1 Water to venturi	 Venturi exit water	RAP mix Run No. PAH R1 Water to venturi	 Venturi exit water
Active carcinogenic species, μg/ℓ				
Benz(a)anthracene	<0.1	<0.1	<0.1	<0.1
Chrysene	0.1	0.1	0.1	0.1
Benzo(b)fluoranthene	ND	ND	ND	ND
Benzo(j)fluoranthene	ND	ND	ND	ND
Benzo(e)pyrene	ND	ND	ND	ND
Benzo(a)pyrene	ND	ND	ND	0.4
Indeno(1,2,3-c,d)-pyrene	ND	ND	ND	ND
Nonactive carcinogenic species, μg/ℓ				
Phenanthrene	10	6.8	7.0	5.0
Anthracene	0.4	ND	ND	ND
Fluoranthene	0.6	0.3	0.7	0.5
Pyrene	1.4	0.6	1.3	0.8
Benzo(k)fluoranthene	ND	ND	ND	ND
Perylene	ND	ND	ND	0.5
Benzo(g,h,i)perylene	ND	ND	ND	ND

ND = Not detected.

During conventional operation, phenanthrene and pyrene were found at levels in excess of 1 part per billion (ppb). Three other species (anthracene, fluoranthrene, and chrysene) were detected at levels of less than 1 ppb. Benz(a)anthracene was detected but not at a quantifiable level.

During RAP operation, phenanthrene and pyrene were the only species found in excess of 1 ppb. Four other species (fluoranthene, perylene, chrysene, and benzo(a)pyrene) were detected at levels less than 1 ppb. The presence of benz(a)anthracene was detected but not at a quantifiable level.

Polynuclear aromatic hydrocarbons were not detected in the scrubber water samples collected at Plant B. Other major organic species quantified in the scrubber water samples from Plant B are presented in Table 4-15.

The scrubber water trace metal analyses for both conventional and RAP mix test runs at Plant A are presented in Table 4-16. There are no significant differences between the scrubber influent and effluent trace metals concentrations for either conventional or RAP operation. Calcium and magnesium were the only species found in excess of 100 ppb.

The emissions at Plants C and D were controlled by baghouses and, therefore, no water samples were obtained for analysis.

TABLE 4-15. MAJOR ORGANICS IN SCRUBBER WATER AT PLANT B[16]

	Water to venturi	Venturi exit water
Major organic species, μg/mℓ		
Phenol	670	870
Cresol	97	200
Methoxy phenol	60	54
C_2-Phenol	46	69
Unknown	75	44
Unknown	60	ND
C_4-Benzene	120	190
C_3-Phenol	106	170
Hydroxymethoxy-phenyl ethanone	106	170

ND = Not detected.

TABLE 4-16. SCRUBBER WATER TRACE METAL ANALYSIS--PLANT A[16]

Trace metal	Conventional mix Run No. PAH C1 Water to venturi	Venturi exit water	RAP mix Run No. PAH R1 Water to venturi	Venturi exit water
Element, μg/mℓ				
Aluminum	<0.05	<0.05	<0.05	<0.05
Beryllium	0.001	<0.005	<0.005	<0.005
Calcium	290	300	300	300
Cadmium	0.007	<0.002	<0.002	<0.002
Chromium	0.004	<0.001	<0.001	<0.001
Iron	0.026	<0.008	<0.008	<0.008
Mercury	<0.03	<0.03	<0.03	<0.03
Magnesium	54	54	54	53
Manganese	0.047	0.053	0.060	0.061
Nickel	<0.003	0.005	0.003	<0.003
Lead	<0.08	<0.084	<0.084	<0.084
Vanadium	0.069	<0.003	<0.003	<0.003
Zinc	<0.003	<0.003	<0.003	<0.003

4.5 REFERENCES FOR CHAPTER 4

1. Trip report. Terry, W., MRI, to Telander, J., EPA:ISB. December 7, 1983. Report of visit to J. H. Strain and Sons Paving Company, Sweetwater, Texas.
2. Trip report. Terry, W., MRI, to Telander, J., EPA:ISB. July 19, 1984. Report of visit to T. J. Campbell Construction Company, Oklahoma City, Oklahoma.
3. Trip report. Shular, J., MRI, to Telander, J., EPA:ISB. August 9, 1983. Report of visits to Mathy Construction Company, Neillsville, Wisconsin.
4. Trip report. Terry, W., MRI, to Telander, J., EPA:ISB. August 28, 1984. Report of visit to ASTEC Industries, Inc., Chattanooga, Tennessee.
5. National Asphalt Pavement Association. The Maintenance and Operation of Exhaust Systems in the Hot Mix Batch Plant. Riverdale, Maryland. 1982. p. 26.
6. U. S. Environmental Protection Agency. A Review of Standards of Performance for New Stationary Sources--Asphalt Concrete Plants. EPA-450/3-79-014. Research Triangle Park, North Carolina p. 4-21.
7. Reference 5, pp. 29-30.
8. Reference 6, pp. 4-19.
9. U. S. Environmental Protection Agency. Inspection Manual for Enforcement of New Source Performance Standards, Asphalt Concrete Plants. EPA-340/1-76-003. Washington, D.C. p. 37.
10. The McIlvaine Company. The Fabric Filter Manual, Volumes 1 and 2. Northbrook, Illinois. September 1983. Ch. IX, pp. 124.4-124.5.
11. Reference 5, p. 23.
12. Reference 5, pp. 45-46.
13. Trip report. Shular, J., MRI, to Telander, J., EPA:ISB. August 15, 1983. Report of visit to A. Metz, Inc. Valparaiso, Indiana.
14. Memo from Green, C., MRI, to 7707-L Project File. February 1, 1985. Compliance Test Reports Collected During NSPS Review.
15. Memo from Butler, J., to Telander, J., EPA/ISB. April 2, 1985. Site Visit Tabulation.
16. Memo from Butler, J., to Telander, J., EPA/ISB. January 18, 1985. Asphalt Concrete Test Data Analysis.

17. Telecon. Butler, J., MRI, with Miller, J., CMI Corporation. June 25, 1985. Discussion of design specification.

18. Telecon. Bulter, J., MRI, with Shave, L., CMI Corporation. June 18, 1985. Discussion of scrubber design specifications.

19. Telecon. Butler, J., MRI, with May, J., ASTEC Industries. June 18, 1985. Discussion of scrubber design specifications.

5. COST ANALYSIS

5.1 COST ANALYSIS OF EMISSION CONTROL DEVICES

The estimated costs of emission control devices for new or modified asphalt concrete plants are presented in this chapter. The objective of this analysis is to quantify the costs associated with two methods of particulate emission control. Model plant parameters were established to represent the size range of facilities that have become subject to the NSPS since the last review. Capital and annualized costs of emission control equipment for the model plants were estimated using the Capital and Operating Costs of Selected Air Pollution Control Systems manual (in December 1977 dollars).[1] These costs were updated to September 1984 dollars using the Chemical Engineering fabricated equipment cost index and indices from the Bureau of Labor Statistics.[2-5] All costs are based on "study" estimates (±30 percent accuracy).

The capital cost of a control system includes the purchase and installation costs of the major control device and necessary auxillaries such as fans and instrumentation; the cost of foundations, piping, electrical wiring, and erection; and the cost of engineering overhead and contingencies.[1,2]

The annualized cost of a control system represents the yearly cost to the company of owning and operating the system. This includes direct operating costs, such as labor, utilities, maintenance and replacement parts, as well as capital related charges such as depreciation, interest, administrative overhead, property taxes, insurance, and product recovery credits.[1,2]

The estimated capital and annualized costs of emission control equipment are presented in Section 5.2. A comparison of the estimated and reported capital costs is presented in Section 5.3. Cost effectiveness of emission control is presented in Section 5.4.

5.2 ESTIMATED CAPITAL AND ANNUALIZED COSTS OF EMISSION CONTROL

Estimated capital and annualized costs are presented for three sizes of model asphalt concrete plants with operating hours per year representing year-round and seasonal operation. The capital and annualized costs are for two emission control devices, a fabric filter and a wet scrubber.

5.2.1 Fabric Filters

Small, medium, and large model asphalt concrete plants were developed to evaluate the cost of emission control by fabric filters on plants installed since September 1984. Parameters describing the model plants and emission control equipment are presented in Table 5-1. The fabric filter emission control system is composed of the fabric filter with pulse-jet cleaning, ductwork (ducts, elbows, damper), induced-draft fan system (fan, motor, V-belt drive, starter, damper), and stack. The exhaust gas flow rate is the critical parameter for costing this type of control device. Exhaust gas flow rates were developed using reported air flow data from industry in combination with design data from control equipment manufacturers.[7]

Table 5-2 presents the estimated capital and annualized costs of fabric filter control devices for the three model plants in September 1984 dollars. The capital cost of fabric filters for the three model plants ranged from $239,000 to $567,000. The annualized cost of fabric filters for the the three model plants ranged from $56,000 to $115,000 for 1,000 h/yr (seasonal) operation and from $61,000 to $119,000 for 1,500 h/yr (year-round) operation.

Table 5-3 presents cost factors used in calculating the annualized costs.

5.2.2 Wet Scrubbers

The capital and annualized costs of wet scrubber control devices were also developed for the three model plants. Parameters describing the plants and emission control equipment are presented in Table 5-1.

The wet scrubber emission control system is composed of a 20-in. w.c. pressure drop, venturi-type scrubber (elbow, separator, pumps, controls), ductwork (ducts, elbows), wastewater disposal pipe, fan system (fan, motor, starter, V-belt drive, damper), and stack. The exhaust gas flow rate and scrubber water flow rate are critical parameters for costing this type of control device. Exhaust gas and water flow rates were developed using reported airflow data from industry in combination with design data from control equipment manufacturers.[7]

Table 5-2 presents the estimated capital and annualized costs of wet scrubber control devices (excluding continuous monitor costs) for the three model plants in September 1984 dollars. The capital cost of venturi scrubbers for the three model plants ranged from $156,000 to $334,000. The annualized cost of venturi scrubbers for the three model plants ranged from $46,000 to $96,000 for 1,000 h/yr operation and from $54,000 to $111,000 for 1,500 h/yr operation.

Table 5-3 presents the cost factors used in calculating the annualized costs.

5.3 COMPARISON OF ESTIMATED AND REPORTED CAPITAL COST DATA

Capital cost data obtained from individual asphalt concrete plants and from vendors were converted to September 1984 dollars for comparison with the estimated capital cost data presented in Section 5.2.[8-10] Table 5-4 presents the estimated and reported costs by plant size and type of control equipment.

5.4 ESTIMATED CAPITAL AND ANNUALIZED COSTS OF CONTINUOUS PRESSURE DROP AND LIQUID FLOW RATE MONITORS

The pressure drop (ΔP) across a wet scrubber and the scrubber water flow rate are two control device parameters that can be used as indicators of how well the control device is operating. In the asphalt concrete industry, these parameters are generally not continuously monitored. However, in the event that a plant were to install and operate continuous monitors, estimates of the capital and annualized costs of these monitors are presented here. The capital and annualized costs of a wet scrubber monitoring system (manometer, flowmeter, recorder) would be $2,903 and $750, respectively. These costs are presented in Table 5-5.

5.5 COST EFFECTIVENESS

Tables 5-6a and 5-6b present the cost effectiveness of wet scrubber (including continuous monitors) and fabric filter control devices on each of the three model plants for seasonal operation (1,000 h/yr) and year-round operation (1,500 h/yr)[7]. Cost effectiveness is the annualized cost of emission control divided by the annual emission reduction. The NSPS (allowable) particulate emissions were calculated for each model plant using the allowable NSPS concentration, the airflow into the device and the seasonal and year-round hours of operation.[1] Uncontrolled emissions, which were assumed to be those entering the fabric filter or wet scrubber, were calculated using an emission factor of 4.9 lb/ton.[7] The annual emission reduction is calculated as uncontrolled emissions minus NSPS (allowable) emissions.

For seasonal operation, the cost effectiveness of controlling emissions from model plants with a fabric filter control device ranges from $130 to $253 per Mg ($118 to $230 per ton). With a wet scrubber control device (including continuous ΔP and liquid flow rate monitors), the cost effectiveness of emission control ranges from $108 to $213 per Mg ($99 to $194 per ton). For year-round operation, the cost effectiveness of control for fabric filters ranges from $89 to $183 per Mg ($81 to $168 per ton). For wet scrubbers with monitors, the cost effectiveness of control ranges from $84 to $166 per Mg ($76 to $151 per ton).

TABLE 5-1. SUMMARY OF ASPHALT CONCRETE MODEL PLANT PARAMETERS

Model plant						
Size	Production rate, Mg/h (tons/h)[a]	Exhaust gas flow rate, m³/min (acfm)[b]	Gas temp. inlet/outlet °C (°F)	Water flow rate, ℓ/min (gpm)[c]	Pressure drop, in. w.c.[d]	Other parameters
I. Fabric filter control						
A. Small	91 (100)	566 (20,000)	163 (325)	N/A	4.5	For all fabric filter-controlled facilities:
B. Medium	277 (250)	1,133 (40,000)	163 (325)	N/A	4.5	Air-to-cloth ratio 6:1; 1,000 h/yr and 1,500 h/yr operation; Nomex bags; pulse jet cleaning; value of mineral filler for product recovery credit $10/ton.
C. Large	363 (400)	1,756 (62,000)	163 (325)	N/A	4.5	
II. Venturi scrubber control						
A. Small	91 (100)	566 (20,000)	163 (325) 71 (160)	628 (166)	20	For all venturi scrubber-controlled facilities: scrubber efficiency = >99%; liquid to gas ratio = 3.1 x10⁻² m³/28 m³·m⁻¹ (8.3 gpm/1,000 acfm)
B. Medium	227 (250)	1,133 (40,000)	163 (325) 71 (160)	1257 (332)	20	
C. Large	363 (400)	1,756 (62,000)	163 (325) 71 (160)	1950 (515)	20	

N/A = Not applicable.

[a] Megagrams (tons) of asphalt produced per hour.
[b] m³/min = actual cubic meters per minute; acfm = actual cubic feet per minute.
[c] ℓ/min = liters per minute; gpm = gallons per minute.
[d] in w.c. = inches water column.

TABLE 5-2. ESTIMATED CAPITAL AND ANNUALIZED COSTS OF PARTICULATE EMISSION CONTROL EQUIPMENT[2]

Model asphalt plant	Model facility size	Capital cost, $[a]	Annualized cost, $[a] (seasonal/ year-round)[b]
I. Fabric filter control			
A	Small	239,000	56,000/ 61,000
B	Medium	386,000	80,000/ 84,000
C	Large	567,000	115,000/ 119,000
II. Wet scrubber control			
A	Small	156,000	46,000/ 54,000
B	Medium	269,000	76,000/ 87,000
C	Large	334,000	96,000/ 111,000

[a] September 1984 dollars rounded to nearest thousand.
[b] Hours of operation: 1,000 h/yr (seasonal); 1,500 h/yr (year-round).

TABLE 5-3. COST FACTORS USED IN CALCULATING THE ANNUALIZED COSTS[2]

Cost item	Wet scrubber	Fabric filter
Operating labor		
Operator	$9.81/h	$9.81/h
Supervisor	← 15% of operator labor	→
Maintenance		
Maintenance labor	$9.81/h	$9.81/h
Materials	← 100% of maintenance labor	→
Utilities		
Electricity	$0.06/kWh	$0.06/kWh
Water cost	$3.00/1,000 gal	N/A
Water use	0.50 gpm/1,000 gal	N/A
Credit for mineral filler	0	$10/ton

N/A = not applicable.

TABLE 5-4. COMPARISON OF ESTIMATED CAPITAL COST OF EMISSION CONTROL WITH REPORTED CAPITAL COST DATA

	Capital cost, 1984 $		%
	Estimated	Reported[a]	Difference[b]
Model facility control device			
Fabric filter			
A. Small	239,000	370,000	-54.8
B. Medium	386,000	412,000	-6.7
C. Large	567,000	561,000	1.1
Wet scrubber			
A. Small	156,000	101,000	35.3
B. Medium	269,000	204,000	24.2
C. Large	334,000	273,000	18.3

[a] Average reported control device capital costs from industry. Reported costs are installed costs of control systems (assumed to include the cost of the control device and all auxiliaries) for new plant construction and installation.

[b] $\% \text{ Difference} = \frac{\text{estimated cost-reported cost}}{\text{estimated cost}} \times 100$

TABLE 5-5. ESTIMATED CAPITAL AND ANNUALIZED COSTS OF CONTINUOUS PRESSURE DROP AND LIQUID FLOW RATE MONITORS[3,11-13]

(September 1984 Dollars)

	Wet scrubber
I. Capital Cost Estimates of Continuous Monitors	
A. Flowmeter	
Impeller/sensor	= $168
Transmitter/display/totalizer	= 309
Output transmitter for records	= 262
	$739
B. Manometer	
Sensor/transmitter	= $739
C. Chart/recorder	
Two-pen recorder	= $1,425
TOTAL	$2,903
II. Annualized Cost of Continuous Monitors	
Recordkeeping (5 min/d, 6 d/wk 25 wk/yr)[a]	= $136
Maintenance labor (4 h/yr)	= 84
Maintenance parts and supplies (pens, charts, etc.)[b]	= 58
Capital recovery cost (16.275 percent of equipment capital cost)[c]	= 472
TOTAL ANNUALIZED COST	$750

[a] Assumes 6 months of plant operation per year.

[b] Assume 2 percent of equipment capital cost.

[c] Based on 10 percent annual interest rate and 10 year capital recovery period.

TABLE 5-6a. COST EFFECTIVENESS OF PARTICULATE EMISSION REDUCTION
(Seasonal Operation, 1,000 h/yr)

Control device	Facility size, Mg/h (tons/h)[a]	Control device annualized cost, $/yr[b]	Particulate emissions, Mg/yr (tons/yr) Uncontrolled	Particulate emissions, Mg/yr (tons/yr) NSPS equivalent	Emission reduction Mg/yr (tons/yr)	Cost effectiveness $/Mg	Cost effectiveness ($/ton)[c]
I. Fabric filter							
A. Small	91 (100)	56,000	222 (245)	1.51 (1.66)	221 (243)	253	(230)
B. Medium	227 (250)	80,000	555 (612)	3.01 (3.32)	552 (609)	144	(132)
C. Large	363 (400)	115,000	890 (981)	4.67 (5.15)	885 (975)	130	(118)
II. Wet scrubber							
A. Small	91 (100)	47,000	222 (245)	1.51 (1.66)	221 (243)	213	(194)
B. Medium	227 (250)	76,000	555 (612)	3.01 (3.32)	552 (609)	138	(125)
C. Large	363 (400)	96,000	890 (981)	4.67 (5.15)	895 (975)	108	(99)

---

[a] Megagrams (tons) of asphalt produced per hour.

[b] September 1984 dollars rounded to nearest thousand. Annualized cost to operate wet scrubber includes cost continuous ΔP and liquid flow rate monitors.

[c] Cost effectiveness = $\frac{\text{Annualized cost}}{\text{Emission reduction}}$; numbers in table may not yield exact cost effectiveness shown due to rounding of annualized cost.

TABLE 5-6b. COST EFFECTIVENESS OF PARTICULATE EMISSION REDUCTION
(Year-round Operation, 1,500 h/yr)

Control device	Facility size, Mg/h (tons/h)[a]	Control device annualized cost, $/yr[b]	Particulate emissions, Mg/yr (tons/yr) Uncontrolled	Particulate emissions, Mg/yr (tons/yr) NSPS equivalent	Emission reduction Mg/yr (tons/yr)	Cost effectiveness[c] $/Mg	Cost effectiveness[c] ($/ton)
I. Fabric filter							
A. Small	91 (100)	61,000	333 (367)	2.26 (2.49)	331 (365)	183	(168)
B. Medium	227 (250)	84,000	621 (685)	4.51 (4.98)	828 (913)	101	(93)
C. Large	363 (400)	119,000	995 (1097)	7.00 (7.72)	1,327 (1,463)	89	(81)
II. Wet scrubber							
A. Small	91 (100)	55,000	333 (367)	2.26 (2.49)	331 (365)	166	(151)
B. Medium	227 (250)	87,000	621 (685)	4.51 (4.98)	828 (913)	106	(96)
C. Large	363 (400)	111,000	995 (1097)	7.00 (7.72)	1,327 (1,463)	84	(76)

[a] Megagrams (tons) of asphalt produced per hour.

[b] September 1984 dollars rounded to nearest thousand. Cost of wet scrubber includes cost for continuous ΔP and liquid flow rate monitors.

[c] Cost effectiveness = $\frac{\text{Annualized cost}}{\text{Emission reduction}}$; numbers in table may not yield exact cost effectiveness shown due to rounding of annualized cost.

5.6 REFERENCES FOR CHAPTER 5

1. Neveril, R. B. Capital and Operating Costs of Selected Air Pollution Control Systems. GARD, Inc. Prepared for the U. S. Environmental Protection Agency. Publication No. EPA-450/5-80-002. December 1978.

2. Memo from Green, C., MRI, to Telander, J., EPA/ISB. January 31, 1985. (Revised April 19, 1985.) Capital and annualized costs of emission control devices for asphalt concrete plants.

3. Economic Indicators. Chemical Engineering. December 24, 1984. p. 7.

4. Employment and Earnings. U.S. Department of Labor. Bureau of Labor Statistics. December 1984. pp. 83-85.

5. Producer Prices and Price Indexes Data for September 1984. U.S. Department of Labor. Bureau of Labor Statistics. September 1984. pp. 109, 130, 133, 134.

6. Telecon. Green, C., MRI, to Waller, M. F., The Asphalt Paving Institute, Raleigh, North Carolina. January 17, 1985. Discussion of the cost of mineral filler material used in the aggregated mix of an asphalt concrete plant.

7. Memo from Butler, J. and Green, C., MRI, to Telander, J., EPA/ISB. March 27, 1985. Final Model Plant Parameters--Asphalt Concrete NSPS Review.

8. Report of Visit--ASTEC Industries, Inc., Chattanooga, Tennessee. Terry, W., to Telander, J., EPA/ISB. August 28, 1984. Asphalt Concrete NSPS Review.

9. Report of Visit--Iowa Manufacturing Co., Cedar Rapids, Iowa. Maxwell, W., to Telander, J., EPA/ISB. September 20, 1983. Asphalt Concrete NSPS Review.

10. Telecon. Cooper, R., MRI, to Krattenmaker, L., Barber-Greene Company. January 5, 1984. Discussion of cost information for small, medium, and large asphalt concrete plants.

11. Telecon. Shular, J., MRI, with Kent Process Control, Inc. March 8, 1983. Cost of chart recorder.

12. Telecon. Shular, J., MRI, to K. Hile, W. K. Hile Company, Inc. March 8, 1983. Cost of continuous monitors.

13. Leter from K. Hile, W. K. Hile Company, Inc., to J. Shular, MRI. February 24, 1983. Cost of continuous monitors.

6. ENFORCEMENT ASPECTS

6.1 ENFORCEMENT

This chapter presents enforcement aspects of the asphalt concrete new source performance standards (NSPS). These are grouped under four main headings: reciprocity waivers, process parameters, control equipment, and visible emissions.

6.1.1 Reciprocity Waivers

Data collected during this review indicate that a number of operating and maintenance factors, in addition to design parameters, affect the performance of an asphalt concrete plant and its associated air pollution control equipment. For this reason, two individual plants of the same make and model may not have the same emission level. Demonstration of compliance with the NSPS by a particular plant should not be used by itself to justify waiving the requirement that a second plant of the same type conduct a performance test.

6.1.2 Process Parameters

As discussed in Chapter 4, process parameters that influence emissions from an asphalt concrete plant are the production rate, the type mix produced, the fuel used for the dryer, and the final product temperature.

6.1.2.1 Production Rate. The survey of test reports collected during this NSPS review indicates that approximately half of the asphalt concrete plants operated at less than 80 percent of their design capacity during compliance testing. Plants that demonstrate compliance with the NSPS when operated below full capacity may be out of compliance when operated at higher production rates. This is especially true for plants that use wet scrubber as control devices. In addition, conducting compliance tests at production rates that are much less than the design capacity will result in emission data that are not representative of normal operation.

As an example, Plant B, discussed in Chapter 4, was tested for compliance with the NSPS at a production rate of 163 tons per hour (tph) and had emissions of 0.02 grains per dry standard cubic foot (gr/dscf). When tested by the EPA at a production rate of 196 tph, the same plant had emissions of 0.13 gr/dscf. This increase in emissions is attributed to the increased production rate and the manner in which the scrubber was operated during the test. Assuming the plant operates 1,500 hours per year, the difference in emissions from these two tests is 12 tons per year. Therefore, it is recommended that NSPS performance tests be conducted at or near full production capcity.

6.1.2.2 Mix Type. As discussed in detail in Chapter 4, mixes that require a large amount of fine material result in more entrained material in the exhaust gas stream from the dryer drum than do mixes containing small amounts of fine material. Surface mixes generally require more fine material than base mixes. Production of a surface mix, therefore, results in more particulate matter in the exhaust gas stream from the dryer drum and a greater loading on the control device than does production of a base mix. Asphalt concrete plants produce both surface and base mixes during normal operation. The practice of testing predominantly during base mix production will not result in testing of the control device under the heaviest concentration of fine materials. Scrubber operation is especially sensitive to the inlet concentration of fine materials. Therefore, it is recommended that NSPS performance tests be conducted during production of a surface mix.

6.1.2.3 Fuel. The most common fuels used at asphalt concrete plants are fuel oil and natural gas. A very limited number of plants have experimented with pulverized coal as a fuel. During the present NSPS review, only three test reports were available for plants using coal as a fuel.[2,3] All of these plants were fabric filter-controlled and 2 of the 3 had particulate emissions greater than 90 mg/dscm (0.04 gr/dscf). One of these two plants was retested while using fuel oil as a fuel and met the NSPS.[2] The other plant has not been retested at this time. The third plant demonstrated particulate emissions of 23 to 30 percent of the NSPS.[3]

The use of coal as a fuel is a recent development in the asphalt concrete industry, and the Agency did not find any existing plants that were originally designed to use coal during this review. Emission control equipment designed to reduce particulate emissions from oil- or gas-fired plants may not be adequately designed or operated to achieve the NSPS emission limit while firing coal. Therefore, operators of asphalt concrete plants need to be aware that conversion from oil or gas to coal may require a change in design or operation to meet the NSPS. Any existing plant not presently subject to the NSPS that switches from gas or oil to coal fuel would be a modified facility.[4] Such a plant would be required to conduct an emission test to demonstrate compliance with the NSPS or to demonstrate that conversion to coal firing does not increase particulate emissions to the atmosphere.

Any existing plant already subject to the NSPS would also have to demonstrate compliance with the standards if it were to switch from oil or gas to coal firing.

6.1.3 Control Equipment

The pressure drop (ΔP) across fabric filters used in the asphalt concrete industry is typically 1.0 to 1.6 kilopascals (kPa) (4 to 6.5 inches water column [in. w.c.]). If the ΔP rises above this level, "blinding" of the bags may occur. A ΔP below normal may indicate tears or leaks in the fabric filter or overcleaning of the bags.

Most venturi scrubbers used in the asphalt concrete industry are designed to operate at a ΔP of 3.8 to 5.0 kPa (15 to 20 in. w.c.).[5,6] Operation at a lower ΔP, as is frequently done, will reduce the efficiency of the scrubber.

The wet scrubber liquid to gas ratio (L/G) recommended by asphalt plant manufacturers ranges from 1.1 to 1.3 liters per cubic meter (ℓ/m^3) [8 to 10 gallons per 1,000 actual cubic feet (gal/1,000 acf)].[7-10] Operation at a lower L/G ratio will reduce the efficiency of the scrubber.

Since many scrubbers in the asphalt concrete industry use water that is recycled through a settling pond, water quality and pond size are closely related. The purpose of the settling pond is to remove suspended solids from the water.

A minimum pond size equal to half the daily flow rate (assuming an 8-hour day) has been recommended by one equipment vendor and by the National Asphalt Pavement Association as proper design to achieve adequate settling.[5,11] It should be noted that this is only a minimum, and, in cases where very fine particulate is present or where a work day longer than 8 hours is practiced, this minimum may not be adequate. The water depth of the pond must also be closely monitored to prevent the pond volume from decreasing as a result of sludge buildup or evaporation of the water.

Several chemical aids are available to maintain water quality. Lime can be used to keep the pH of the water from dropping, and various flocculants can be used to aid in the settling of suspended solids. It should be noted that, while flocculants aid particulate settling, they should not be expected to compensate for an inadequate pond size. One equipment manufacturer recommends a maximum suspended solids concentration of 500 parts per million (ppm) and a minimum pH of 5.[5]

Excess dissolved solids in the scrubber water may decrease the efficiency of a scrubber. However, this parameter is not typically monitored, and guidelines on what dissolved solids level is "excessive" are not available.[5] One method of controlling dissolved solids is to replace a portion of the scrubber pond water with fresh water periodically.

6.1.4 Blue Haze Emissions

As discussed in Chapter 4, approximately half of the plants visited reported the presence of blue haze emissions during production of recycled mix. The blue haze generally developed downwind of the plant rather than at the stack vertex. No blue haze emissions in excess of 20 percent opacity were observed during the plant visits or emissions testing program. Observers of visible emissions during NSPS performance tests should note that condensing emissions that develop downwind of the plant are not included in the Method 9 observations.

6.1.5 Visible Emissions

The present NSPS for asphalt concrete plants includes a visible emission standard of 20 percent opacity. Visible emission readings are often difficult to make at a scrubber-controlled plant due to the presence of an attached steam plume. Steam plumes are sometimes observed at plants controlled by fabric filters; however, these plumes are usually detached and not as dense as those observed at scrubber-controlled plants. EPA Reference Method 9 specifies that visible emissions should be evaluated between the stack and the steam plume for detached plumes, or after disappearance of the steam plume for attached plumes. Visible emissions are, therefore, usually read at the stack vertex at fabric filter-controlled plants and downstream of the steam plume at scrubber-controlled plants. After the disappearance of the steam plume, the remaining plume is lightened by dispersion. In contrast, the blue haze sometimes observed with RAP mixes appears to darken as the plume cools and moves away from the stack. Because of these interferences, the opacity of visible emissions in a scrubber exhaust plume may not be a consistent indicator of the performance of the scrubber.

As discussed in Chapter 4, the test reports collected during this NSPS review indicate a high non-compliance rate for scrubber-controlled plants. These test reports and discussions with plant personnel suggest that wet scrubber performance is often allowed to deteriorate by operating at a ΔP and liquid flow rate below the levels necessary to meet compliance. For the reasons just discussed, visible emissions may not be a consistent indicator of this deterioration in performance. Monitoring of ΔP and liquid flow rate to supplement visible emissions would provide a better indication of proper operation and maintenance for plant and enforcement personnel. Operation of a wet scrubber at ΔP and liquid flow rate levels below those recorded during successful compliance testing would indicate a potential decrease in scrubber performance and an increase in emissions.

6.2 REFERENCES FOR CHAPTER 6

1. Trip report. Butler, J., MRI, to Clowers, M., EPA:ISB. April 17, 1984. Report of visit to Sloan Construction Company, Ormond Beach, Florida.

2. Letter and attachments from Andrews, D., Kentucky Division of Air Pollution Control, to Butler, J., MRI. January 30, 1985. Three compliance tests on two coal-fired asphalt plants.

3. Letter and attachments from Sprouse, S. M., ASTEC Industries, Inc. March 26, 1985. Emission test report and production literature.

4. Memorandum from Reich, E. E., EPA, to Wilburn, J. T., EPA. April 4, 1985. Asphalt Concrete Plant NSPS Determination.

5. Telecon. Butler, J., MRI, with Wagner, L., ASTEC Industries, Inc. October 8, 1984. Design and operating parameters for scrubber and baghouse controlled asphalt concrete plants.

6. National Asphalt Pavement Association. The Maintenance and Operation of Exhaust Systems in the Hot Mix Batch Plant. Information Series 52 (2nd edition) and 52A (combined volumes). College Park, Maryland. February 1980. pp. 26.

7. Telecon. Butler, J., MRI, with May, J., ASTEC Industries, Inc. June 18, 1985. ΔP and L/G requirments for scurbber-controlled plants.

8. Telecon. Butler, J., MRI, with Binz, L., Barber-Greene Co., Inc. June 18, 1984. ΔP and L/G requirements for scrubber-controlled plants.

9. Telecon. Butler, J., MRI, with Shaves, L., CMI Corporation June 18, 1984. ΔP and L/G requirements for scrubber-controlled plants.

10. Telecon. Butler, J., MRI, with Linkletter, D. Iowa Mfg. Co. June 18, 1984. ΔP and L/G requirments for scrubber-controlled plants.

11. Reference 6, pp. 6A.

APPENDIX A
EMISSION SOURCE TEST DATA

The test results from EPA-conducted emission tests for four asphalt concrete plants are presented in this appendix. These test results include data that were excluded from Table 4-6 in Chapter 4 and the reasons for their exclusion.

A.1 Description of Sources

A brief description of the four plant sites tested and the operating conditions of the process unit and control device at each plant site is presented in this section.

A.1.1 Plant A

Plant A is a venturi-scrubber controlled drum-mix plant. Tests were conducted during production of both conventional and approximately 25 percent recycled asphalt pavement (RAP) mixes. Plant A has a design capacity range of 227 to 318 megagrams/hour (Mg/h) [250 to 350 tons/hour (tons/h)] and typically operates at approximately 218 Mg/h (240 tons/h). During testing the plant production averaged 204 Mg/h (232 tons/h) of conventional mix and 218 Mg/h (240 tons/h) of RAP mix. The pressure drop (ΔP) across the venturi averaged 3.23 kilopascals (kPa) [13.65 inches water column (in. w.c.)] and the liquid-to-gas ratio averaged 0.017 gallons per standard cubic foot (gal/scf) during testing.

The particulate and total organic carbon (TOC) emission test results for Plant A are presented in Tables A-1 through A-4. The total organic carbon samples from Plant A were originally analyzed by an unapproved method (TOC-1) that resulted in the inclusion of inorganic carbon in the reported TOC values. These are the values presented in Tables A-1 through A-4. These samples were also analyzed by an ether/chloroform extraction method (ECE or extractable organics). The samples were reanalyzed by the TOC-1 method and by the approved Method 5E analysis method (TOC-2) when the samples were approximately 9 months old. The TOC-1 analysis indicated that the samples had deteriorated during this 9-month period. The results of these analyses are presented in Table A-5. Due to these problems in testing methodology and analytical procedures, the TOC results from Plant A were not used in this study. The extractable organic results (ECE) were also not used in this study because they are not directly comparable to TOC results obtained using a different analysis method.

The visible emissions observed at Plant A are described in Tables A-6 through A-8 and in Figures A-1 through A-3. The highest single reading was 10 percent and the highest 6-minute average ranged from 1.5 percent to 5.8 percent for the three test runs during which visible emissions were observed.

A.1.2 Plant B

Plant B is a venturi-scrubber controlled, portable, drum-mix plant. Tests were conducted only during production of approximately 50 percent RAP mixes. Plant B has a design capacity of 229 Mg/h (252 tons/h) at 5 percent moisture removal. During testing the plant averaged 181 Mg/h (199 tons/h). The ΔP across the venturi averaged 4.67 kPa (19 in. w.c.), and the liquid-to-gas ratio averaged 0.021 gal/scf during testing.

The particulate and TOC emission test results for Plant B are presented in Tables A-9 and A-10. The visible emissions observed at Plant B are described in Tables A-11 through A-14 and in Figures A-4 through A-7. The highest single reading was 25 percent and the highest 6-minute average ranged from 11.9 percent to 17.5 percent for the 4 test runs during which visible emissions were observed.

A.1.3 Plant C

Plant C is a baghouse-controlled, stationary drum-mix plant. Tests were conducted during production of both conventional mix and approximately 28 percent RAP mixes. Plant C has a design capacity of 386 Mg/h (425 tons/h) at 5 percent moisture removal. The design air-to-cloth ratio was 5.6 acfm/ft^2. During testing the plant production averaged 217 Mg/h (239 tons/h) of conventional mix and 310 Mg/h (342 tons/h) of

RAP mix. The ΔP across the baghouse averaged 1.3 kPa (5.1 in. w.c.) during production of conventional mix and 1.0 kPa (4.0 in. w.c.) during production of RAP mix.

The particulate and TOC emission test results for Plant C are presented in Tables A-15 through A-18. The TOC samples collected at Plant C were contaminated with an organic solvent used to clean the impinger walls. Therefore, the TOC results from Plant C were not used in this study.

The visible emissions observed at Plant C are described in Tables A-19 through A-27 and in Figures A-8 and A-9. As discussed in Chapter 4, field data sheets from Plant C indicate that some or all of the opacity readings at Plant C were made within the steam plume; therefore, these values were not used in this study.

A.1.4 Plant D

Plant D is a baghouse-controlled, portable drum-mix plant. Tests were conducted during production of both conventional and approximately 50 percent RAP mixes. Plant D has a design capacity of 391 Mg/h (430 tons/h) at 5 percent moisture removal and typically operates at 273-318 Mg/h (300-350 tons/h). The design air-to-cloth ratio was 6.3 acfm/ft^2. During testing the plant production averaged 271 Mg/h (299 tons/h) of conventional mix and 288 Mg/h (317 tons/h) of RAP mix. The ΔP across the baghouse averaged 1.4 kPa (5.6 in. w.c.) during production of conventional mix and 1.2 kPa (4.7 in. w.c.) during production of RAP mix.

The particulate and TOC emission test results for Plant D are presented in Tables A-28 through A-31. The visible emissions observed at Plant D are described in Tables A-32 and A-33 and in Figures A-10 and A-11. Visible emissions were observed during one conventional-mix test run and during one RAP-mix test run. During production of conventional mix the highest single reading was 5 percent and the highest 6-minute average was 1.25 percent. During production of RAP mix the highest single reading was 5 percent and the highest 6-minute average was 5.0 percent.

A.2 Summary of Test Data

The EPA-conducted and EPA-approved test data are summarized in this section. Metric/English conversions and test series averages may not convert exactly due to independent rounding of data.

TABLE A-1. SUMMARY OF UNCONTROLLED EMISSION TEST RESULTS--PLANT A--CONVENTIONAL MIX PROCESS UNIT: DRUM PLANT MIX

Data	Run No. C-1	Run No. C-2	Run No. C-3	Run No.	Average for test series
General					
Date	11/12/83	11/13/83	11/13/83		--
Sampling time, min	48	48	48		--
Isokinetic ratio, percent	109.9	113.3	103.8		--
Production rate, Mg/h (tons/h)	221 (244)	213 (235)	193 (213)		210 (231)
Gas stream data					
Temperature, °C (°F)	147.6 (297.6)	142.7 (288.8)	150.9 (303.6)		147.1 (296.7)
Moisture, percent	38.01	39.6	36.71		38.11
Flow rate, m^3/s (acfm)	13.46 (28,523)	13.68 (28,974)	14.31 (30,312)		13.82 (29,269.7)
Flow rate, dsm^3/s (dscfm)	5.52 (11,699)	5.53 (11,724)	5.91 (12,516)		5.65 (11,980)
Particulate emissions					
mg/dscm (gr/dscf)	17,400 (7.6)	19,400 (8.49)	12,800 (5.58)		16,500 (7.22)
g/s (lb/h)	96.1 (762)	115 (910)	75.5 (599)		95.5 (757)
kg/Mg (lb/ton)	1.56 (3.12)	1.935 (3.87)	1.405 (2.81)		1.635 (3.27)
Total Organic Carbon--TOC					
mg/dscm (gr/dscf)	470 (0.205)	995 (0.434)	681 (0.297)		715 (0.312)
g/s (lb/h)	2.59 (20.5)	5.50 (43.6)	4.01 (31.8)		4.03 (32.0)
kg/Mg (lb/ton)	0.042 (0.0840)	0.093 (0.186)	0.0745 (0.0149)		0.0695 (0.139)

TABLE A-2. SUMMARY OF CONTROLLED EMISSION TEST RESULTS--PLANT A--CONVENTIONAL MIX PROCESS UNIT: DRUM PLANT MIX

Data	Run No. C-1	Run No. C-2	Run No. C-3	Run No.	Average for test series
General					
Date	11/12/83	11/13/83	11/14/83		--
Sampling time, min	96	96	96		--
Isokinetic ratio, percent	105	100.3	101.8		--
Production rate, Mg/h (tons/h)	221 (244)	213 (235)	193 (213)		210 (231)
Gas stream data					
Temperature, °C (°F)	70.4 (158.7)	68.2 (154.8)	67.0 (152.6)		68.5 (155.4)
Moisture, percent	34.29	32.26	29.73		32.09
Flow rate, m^3/s (acfm)	10.03 (21,255)	9.69 (20,533)	9.71 (20,579)		9.81 (29,789)
Flow rate, dsm^3/s (dscfm)	5.37 (11,367)	5.38 (11,400)	5.57 (11,811)		5.44 (11,526)
Particulate emissions					
mg/dscm (gr/dscf)	126 (0.0550)	186 (0.0814)	76 (0.0332)		129 (0.0565)
g/s (lb/h)	0.697 (5.53)	1.05 (8.29)	0.435 (3.45)		0.726 (5.76)
kg/Mg (lb/ton)	0.0113 (0.0226)	0.0177 (0.0353)	0.0081 (0.0162)		0.0124 (0.0247)
Total Organic Carbon--TOC					
mg/dscm (gr/dscf)	122 (0.0532)	319 (0.139)	296 (0.129)		245 (0.107)
g/s (lb/h)	0.697 (5.34)	1.05 (14.2)	0.435 (13.4)		0.726 (11.0)
kg/Mg (lb/ton)	0.0110 (0.0219)	0.0302 (0.0604)	0.0315 (0.0629)		0.0238 (0.0476)

TABLE A-3. SUMMARY OF UNCONTROLLED EMISSION TEST RESULTS--PLANT A--RAP MIX PROCESS UNIT: DRUM PLANT MIX

Data	Run No. R-1	Run No. R-2	Run No. R-3	Run No.	Average for test series
General					
Date	11/11/83	11/11/83	11/12/83		--
Sampling time, min	48	42	48		--
Isokinetic ratio, percent	94.8	116.9	110.6		--
Production rate, Mg/h (tons/h)	208 (229)	227 (250)	214 (236)		216.3 (238.3)
Gas stream data					
Temperature, °C (°F)	146.8 (296.2)	156.4 (313.6)	158.3 (317.0)		153.8 (308.9)
Moisture, percent	24.44	31.48	27.74		27.89
Flow rate, m^3/s (acfm)	13.8 (29,241)	12.9 (27,367)	14.2 (30,060)		13.6 (28,889)
Flow rate, dsm^3/s (dscfm)	6.98 (14,797)	5.79 (12,275)	6.61 (14,012)		6.46 (13,695)
Particulate emissions					
mg/dscm (gr/dscf)	7,420 (3.24)	10,000 (4.37)	8,590 (3.75)		8,670 (3.79)
g/s (lb/h)	51.8 (411)	62.9 (499)	59.8 (474)		58.2 (461)
kg/Mg (lb/ton)	0.895 (1.79)	1.00 (2.00)	1.005 (2.01)		0.97 (1.94)
Total Organic Carbon--TOC					
mg/dscm (gr/dscf)	1,030 (0.448)	1,500 (0.655)	1,160 (0.504)		1,230 (0.536)
g/s (lb/h)	7.16 (56.8)	8.71 (69.1)	7.63 (60.5)		7.83 (62.1)
kg/Mg (lb/ton)	0.124 (0.248)	0.138 (0.276)	0.128 (0.256)		0.131 (0.261)

TABLE A-4. SUMMARY OF CONTROLLED EMISSION TEST RESULTS--PLANT A--RAP MIX PROCESS UNITS: DRUM PLANT MIX

Data	Run No. R-1	Run No. R-2	Run No. R-3	Run No.	Average for test series
General					
Date	11/11/83	11/11/83	11/12/83		--
Sampling time, min	93	96	96		--
Isokinetic ratio, percent	104.5	116.3	106.6		--
Production rate, Mg/h (tons/h)	208 (229)	227 (250)	214 (236)		216 (238)
Gas stream data					
Temperature, °C (°F)	63.6 (146.6)	66.8 (152.3)	61.4 (142.5)		63.9 (147.1)
Moisture, percent	21.28	30.63	20.68		24.20
Flow rate, m^3/s (acfm)	10.0 (21,180)	10.36 (21,951)	9.95 (21,076)		10.10 (21,402)
Flow rate, dsm^3/s (dscfm)	6.60 (13,982)	5.97 (12,650)	6.60 (13,973)		6.39 (13,535)
Particulate emissions					
mg/dscm (gr/dscf)	51.9 (0.0227)	52.5 (0.0229)	65.4 (0.0286)		56.6 (0.0247)
g/s (lb/h)	0.343 2.72	0.348 2.76	0.431 3.42		0.374 2.97
kg/Mg (lb/ton)	0.0050 (0.0119)	0.0055 (0.0110)	0.0073 (0.0145)		0.0063 (0.0125)
Total Organic Carbon--TOC					
mg/dscm (gr/dscf)	136 (0.0592)	224 (0.0975)	365 (0.159)		242 (0.105)
g/s (lb/h)	0.894 (7.09)	1.40 (11.1)	2.40 (19.0)		1.54 (12.4)
kg/Mg (lb/ton)	0.0155 (0.0310)	0.0223 (0.0445)	0.0403 (0.0805)		0.0260 (0.0520)

TABLE A-5. ORGANIC EMISSION DATA AT PLANT A USING VARIOUS TEST METHODS

Run no.	Inlet--uncontrolled				Outlet--controlled			
	Original TOC-1[a] mg/dscm (gr/dscf)	Original ECE[b] mg/dscm (gr/dscf)	Reanalyzed TOC-1[c] mg/dscm (gr/dscf)	Reanalyzed TOC-2[d] mg/dscm (gr/dscf)	Original TOC-1[a] mg/dscm (gr/dscf)	Original ECE[b] mg/dscm (gr/dscf)	Reanalyzed TOC-1[c] mg/dscm (gr/dscf)	Reanalyzed TOC-2[d] mg/dscm (gr/dscf)
C-1	470 (0.205)	6.86 (0.003)	2,190 (0.958)	554 (0.242)	121 (0.0531)	52.6 (0.023)	431 (0.188)	93.9 (0.0410)
C-2	996 (0.435)	25.2 (0.011)	1,560 (0.684)	117 (0.0512)	320 (0.139)	29.7 (0.013)	353 (0.154)	115 (0.0502)
C-3	681 (0.298)	38.9 (0.017)	1,380 (0.602)	129 (0.0562)	295 (0.129)	43.5 (0.019)	533 (0.233)	113 (0.0494)
R-1	1,030 (0.449)	34.5 (0.019)	1,570 (0.685)	122 (0.0534)	136 (0.0593)	27.5 (0.012)	664 (0.290)	147 (0.0644)
R-2	1,500 (0.654)	18.3 (0.008)	2,660 (1.16)	120 (0.0523)	223 (0.0974)	66.4 (0.029)	364 (0.159)	96.4 (0.0421)
R-3	1,160 (0.505)	32.0 (0.014)	2,200 (0.963)	890 (0.389)	364 (0.159)	36.6 (0.016)	434 (0.190)	42.4 (0.0185)

[a] Original analysis by an unapproved method (TOC-1) resulting in inclusion of inorganic carbon in TOC values.

[b] Analysis by ether/chloroform extraction method (extractable organics).

[c] Reanalysis by unapproved TOC-1 method after 9-month delay.

[d] Reanalysis by approved Method 5E analysis method (TOC-2) after 9-month delay.

TABLE A-6. SUMMARY OF VISIBLE EMISSIONS--PLANT A--RAP MIX

Date	11/10/83
Run No.	Preliminary
Control device	Wet scrubber
Height of point of discharge, ft	30
Distance from observer to discharge point, ft	300
Direction of observer from discharge point	South
Description of background	Sky
Description of sky	Clear
Wind direction	North
Wind velocity, mph	20
Color of plume	White
Period of observation	1000-1620
Highest single reading, percent	5
Highest 6-minute average opacity, percent	2.7

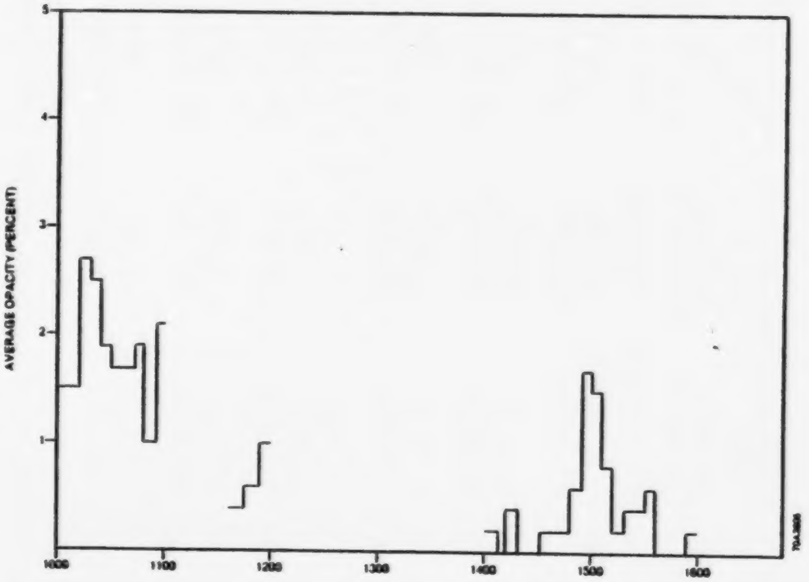


Figure A-1. Six-minute averages of November 10, 1983.
Opacity readings on venturi scrubber stack during recycle operation.

TABLE A-7. SUMMARY OF VISIBLE EMISSIONS--PLANT A--CONVENTIONAL MIX

Date	11/12/83
Run No.	C-1
Control device	Wet scrubber
Height of point of discharge, ft	30
Distance from observer to discharge point, ft	150
Direction of observer from discharge point	East
Description of background	Sky
Description of sky	Blue; scattered clouds
Wind direction	Southeast
Wind velocity, mph	3-15
Color of plume	White
Period of observation	1130-1429
Highest single reading, percent	5
Highest 6-minute average opacity, percent	1.5

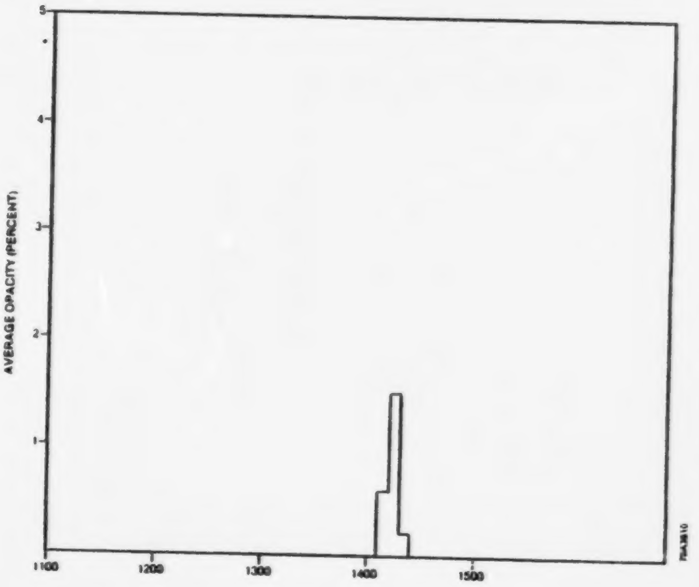


Figure A-2. Six-minute averages of November 12, 1983. Opacity readings on the venturi scrubber stack during conventional operations.

TABLE A-8. SUMMARY OF VISIBLE EMISSIONS--PLANT A--RAP MIX

Date	11/11/83
Run No.	R-1
Control device	Wet scrubber
Height of point of discharge, ft	30
Distance from observer to discharge point, ft	50-125
Direction of observer from discharge point	Northeast-Southwest
Description of background	Sky
Description of sky	Clear
Wind direction	0819-1136 North; 1308-1718 South
Wind velocity, mph	1-5
Color of plume	White
Period of observation	0837-1441
Highest single reading, percent	10
Highest 6-minute average opacity, percent	5.8

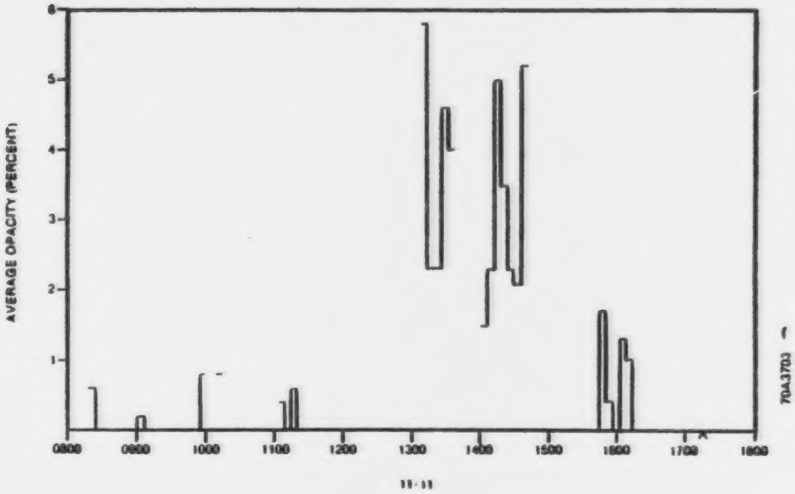


Figure A-3. Six-minute averages of November 11, 1983.
Opacity readings on venturi scrubber stack during recycle operation.

TABLE A-9. SUMMARY OF UNCONTROLLED EMISSION TEST RESULTS--PLANT B--RAP MIX PROCESS UNIT: DRUM PLANT MIX

Data	Run No. R-1	Run No. R-2	Run No. R-3	Run No. R-4	Average for test series
General					
Date	5/8/84	5/10/84	5/10/84	5/10/84	--
Sampling time, min	32	32	32	32	--
Isokinetic ratio, percent	99.7	101.2	97.5	101.5	--
Production rate, Mg/h (tons/h)	188 (207)	172 (190)	174 (192)	186 (205)	178 (196)
Gas stream data					
Temperature, °C (°F)	141.6 (286.9)	150.9 (303.7)	143.7 (290.7)	145.2 (293.4)	145.4 (296)
Moisture, percent	30.31	28.95	30.4	32.2	30.5
Flow rate, m^3/s (acfm)	18.05 (38,242)	17.31 (36,682)	17.23 (36,504)	16.30 (34,524)	17.22 (36,488)
Flow rate, dsm^3/s (dscfm)	8.93 (18,914)	8.56 (18,129)	8.49 (17,993)	7.80 (16,521)	8.44 (17,889)
Particulate emissions					
mg/dscm (gr/dscf)	18,500 (8.09)	12,700 (5.54)	14,100 (6.15)	12,100 (5.28)	13,000 (5.66)
g/s (lb/h)	165 (1,310)	109 (861)	120 (949)	94.3 (748)	108 (853)
kg/Mg (lb/ton)	3.165 (6.33)	2.265 (4.53)	2.47 (4.94)	1.825 (3.65)	2.185 (4.37)
Total Organic Carbon--TOC					
mg/dscm (gr/dscf)	799 (0.349)	117 (0.051)	124 (0.054)	119 (0.052)	120 (0.052)
g/s (lb/h)	7.11 (56.4)	0.999 (7.92)	1.06 (8.40)	0.918 (7.28)	0.992 (7.87)
kg/Mg (lb/ton)	0.136 (0.272)	0.021 (0.042)	0.022 (0.044)	0.19 (0.036)	0.021 (0.041)

TABLE A-10. SUMMARY OF CONTROLLED EMISSION TEST RESULTS--PLANT B--RAP MIX PROCESS UNIT: DRUM PLANT MIX

Data	Run No. R-1	Run No. R-2	Run No. R-3	Run No. R-4	Average for test series[a]
General					
Date	5/8/84	5/10/84	5/10/84	5/10/84	--
Sampling time, min	119	72	72	72	--
Isokinetic ratio, percent	82.6	102.1	104.7	102.3	--
Production rate, Mg/h (tons/h)	190 (209)	172 (190)	177 (195)	185 (204)	178 (196)
Gas stream data					
Temperature, °C (°F)	70.5 (158.8)	67.7 (153.8)	71.1 (160)	71.5 (160.8)	70.1 (158.2)
Moisture, percent	29.51	24.8	30.2	30.4	28.5
Flow rate, m^3/s (acfm)	13.65 (28,909)	12.86 (27,241)	14.02 (29,073)	13.15 (27,856)	13.34 (28,057)
Flow rate, dsm^3/s (dscfm)	8.30 (17,592)	8.42 (17,833)	8.26 (17,503)	7.88 (16,700)	8.19 (17,345)
Particulate emissions					
mg/dscm (gr/dscf)	263 (0.115)	298 (0.130)	327 (0.143)	259 (0.113)	295 (0.129)
g/s (lb/h)	2.00 (15.9)	2.51 (19.9)	2.70 (21.4)	2.03 (16.1)	2.41 (19.1)
kg/Mg (lb/ton)	0.038 (0.076)	0.0525 (0.105)	0.055 (0.110)	0.0395 (0.079)	0.049 (0.098)
Total Organic Carbon--TOC					
mg/dscm (gr/dscf)	52.6 (0.023)	57.2 (0.025)	57.2 (0.025)	43.5 (0.019)	52.6 (0.023)
g/s (lb/h)	0.438 (3.47)	0.487 (3.86)	0.467 (3.70)	0.351 (2.78)	0.435 (3.45)
kg/Mg (lb/ton)	0.008 (0.017)	0.010 (0.020)	0.0095 (0.019)	0.007 (0.014)	0.009 (0.018)

[a] Average for the test series was based on R-2, R-3, and R-4 because R-1 was less than 90 percent isokinetic.

TABLE A-11. SUMMARY OF VISIBLE EMISSIONS--PLANT B--RAP MIX

Date	5/8/84
Run No.	R-1
Control device	Wet scrubber
Height of point of discharge, ft	30
Distance from observer to discharge point, ft	175
Direction of observer from discharge point	Northeast
Description of background	Sky
Description of sky	Clear
Wind direction	East
Wind velocity, mph	10-15
Color of plume	White
Period of observation	1425-1745
Highest single reading, percent	20
Highest 6-minute average opacity, percent	11.9

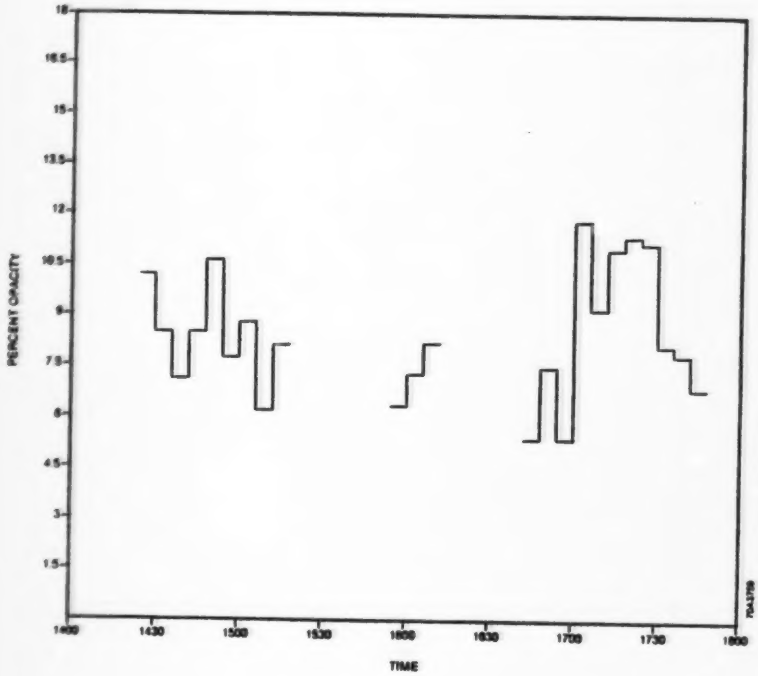


Figure A-4. Six-minute averages of the visible emissions from the venturi scrubber stack during particulate/TOC Run 1 at the Sloan Construction Company Asphalt Concrete Plant, Cocoa, Florida, on May 8, 1984.

TABLE A-12. SUMMARY OF VISIBLE EMISSIONS--PLANT B--RAP MIX

Date	5/10/84
Run No.	R-2
Control device	Wet scrubber
Height of point of discharge, ft	30
Distance from observer to discharge point, ft	150
Direction of observer from discharge point	East
Description of background	Sky
Description of sky	Clear--partly cloudy
Wind direction	Northwest
Wind velocity, mph	5-10
Color of plume	White
Period of observation	0800-1027
Highest single reading, percent	25
Highest 6-minute average opacity, percent	17.5

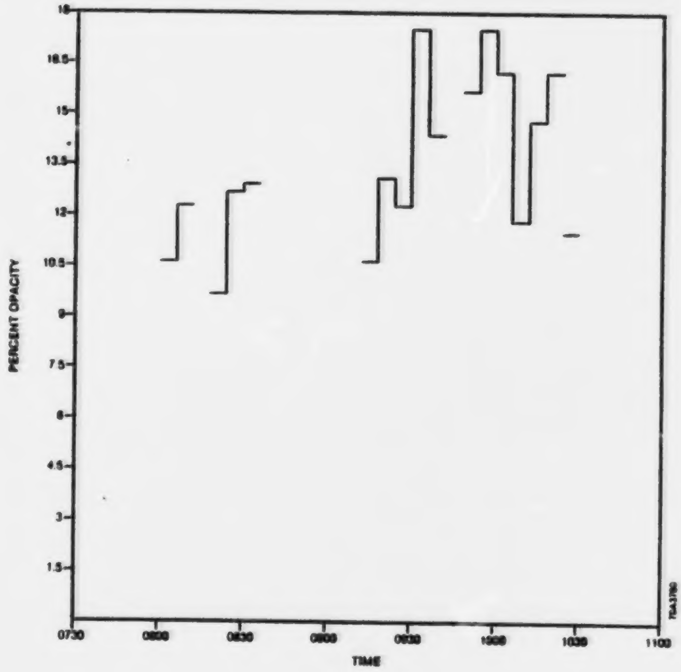


Figure A-5. Six-minute averages of the visible emissions from the venturi scrubber stack during particulate/TOC Run 2 of the Sloan Construction Company Asphalt Concrete Plant, Cocoa, Florida, on May 10, 1984.

TABLE A-13. SUMMARY OF VISIBLE EMISSIONS--PLANT B--RAP MIX

Date	5/10/84
Run No.	R-3
Control device	Wet scrubber
Height of point of discharge, ft	30
Distance from observer to discharge point, ft	150
Direction of observer from discharge point	East
Description of background	Sky
Description of sky	Clear
Wind direction	Northwest
Wind velocity, mph	5-10
Color of plume	White
Period of observation	1139-1410
Highest single reading, percent	25
Highest 6-minute average opacity, percent	16.9

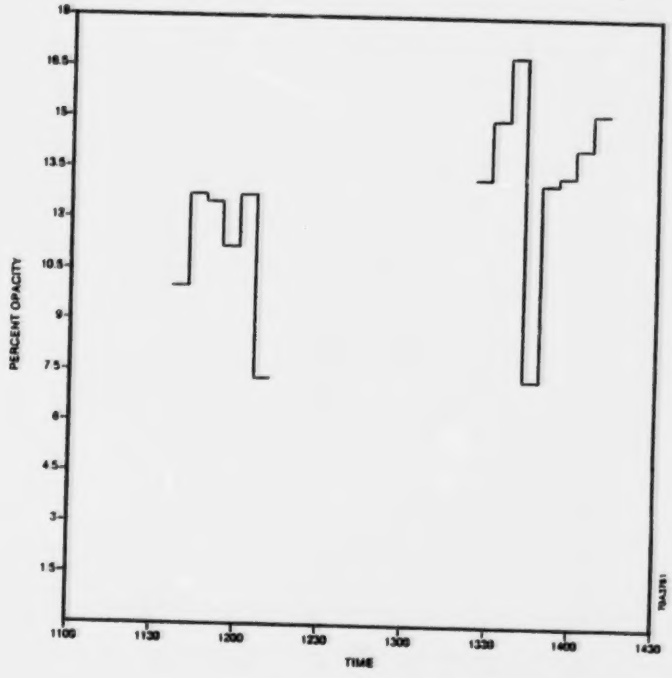


Figure A-6. Six-minute averages of the visible emission from the venturi scrubber stack during particulate/TOC Run 3 at the Sloan Construction Company Asphalt Concrete Plant, Cocoa, Florida, on May 10, 1984.

TABLE A-14. SUMMARY OF VISIBLE EMISSIONS--PLANT B--RAP MIX

Date	5/10/84
Run No.	R-4
Control device	Wet scrubber
Height of point of discharge, ft	30
Distance from observer to discharge point, ft	150
Direction of observer from discharge point	West
Description of background	Sky
Description of sky	Partly cloudy
Wind direction	North
Wind velocity, mph	5-10
Color of plume	White
Period of observation	1540-1659
Highest single reading, percent	20
Highest 6-minute average opacity, percent	12.9

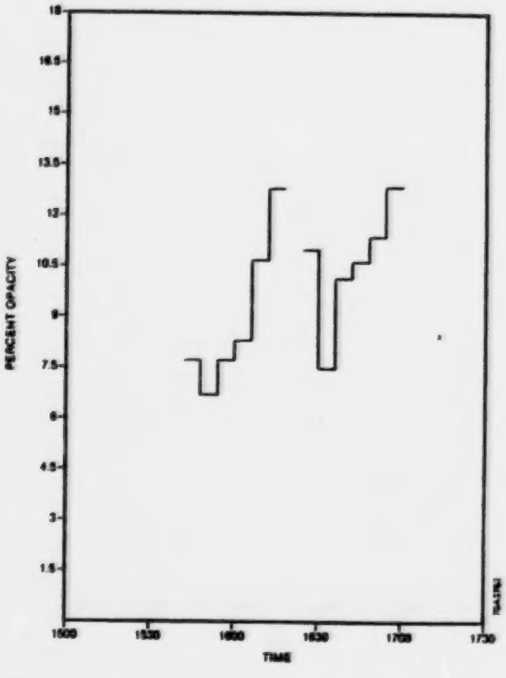


Figure A-7. Six-minute averages of the visible emissions from the venturi scrubber stack during particulate/TOC Run 4 at the Sloan Construction Company Asphalt Concrete Plant, Cocoa, Florida, on May 10, 1984.

TABLE A-15. SUMMARY OF UNCONTROLLED EMISSION TEST RESULTS--PLANT C--CONVENTIONAL MIX PROCESS UNIT: DRUM PLANT MIX

Data	Run No. C-1	Run No. C-2	Run No. C-3	Run No.	Average for test series
General					
Date	7/24/84	7/25/84	7/25-26/84		--
Sampling time, min	75	75	75		--
Isokinetic ratio, percent	94.6	101.3	106.4		--
Production rate, Mg/h	220	217	206		214
(tons/h)	(242)	(239)	(227)		(236)
Gas stream data					
Temperature, °C	152.7	202.2	173.3		176.1
(°F)	(307)	(396)	(344)		(349)
Moisture, percent	24.8	27.1	31.4		27.8
Flow rate, m^3/s	23.72	26.32	22.45		24.17
(acfm)	(50,259.5)	(55,770.8)	(47,569)		(51,199.8)
Flow rate, dsm^3/s	12.28	11.84	10.14		11.42
(dscfm)	(26,008)	(25,095)	(21,483)		(24,195)
Particulate emissions					
mg/dscm	43,479.31	34,433.89	38,215.40		38,709.53
(gr/dscf)	(19.006)	(15.052)	(16.705)		(16.921)
g/s	535.53	407.95	387.567		443.68
(lb/h)	(4,250.32)	(3,237.77)	(3,076.07)		(3,521.086)
kg/Mg	8.78	6.78	6.78		7.46
(lb/ton)	(17.56)	(13.55)	(13.55)		(14.92)
Total Organic Carbon--TOC					
mg/dscm	43.46	475.83	375.176		298.15
(gr/dscf)	(0.019)	(0.208)	(0.164)		(0.130)
g/s	0.532	5.64	3.816		3.33
(lb/h)	(4.22)	(44.757)	(30.290)		(26.422)
kg/Mg	(0.0085)	(0.0935)	(0.0665)		(0.056)
(lb/ton)	(0.017)	(0.187)	(0.133)		(0.112)

TABLE A-16. SUMMARY OF CONTROLLED EMISSION TEST RESULTS--PLANT C--CONVENTIONAL MIX PROCESS UNITS: DRUM PLANT MIX

Data	Run No. C-1	Run No. C-2	Run No. C-3	Run No.	Average for test series
General					
Date	7/24/84	7/25/84	7/25-26/84		--
Sampling time, min	64	60	64		--
Isokinetic ratio, percent	91.5	94.0	103.9		--
Production rate, Mg/h	219.5	216.8	205.9		214.1
(tons/h)	(242)	(239)	(227)		(236)
Gas stream data					
Temperature, °C	128.9	140.5	131.7		133.9
(°F)	(264)	(285)	(269)		(273)
Moisture, percent	28.3	25.6	33.9		29.3
Flow rate, m^3/s	18.7	22.1	18.9		19.9
(acfm)	(39,642.7)	(46,783.9)	(40,007.8)		(42,144.8)
Flow rate, dsm^3/s	9.8	11.7	9.1		10.2
(dscfm)	(20,823)	(24,804)	(19,261)		(21,620)
Particulate emissions					
mg/dscm	25.164	297.396	2,951.08		1,091.21
(gr/dscf)	(0.011)	(0.130)	(1.29)		(0.477)
g/s	0.237	3.492	26.82		10.18
(lb/h)	(1.88)	(27.718)	(212.88)		(80.82)
kg/Mg	0.0039	0.058	0.469		0.171
(lb/ton)	(0.0077)	(0.116)	(0.938)		(0.342)
Total Organic Carbon--TOC					
mg/dscm	947.09	75.49	908.2		643.59
(gr/dscf)	(0.414)	(0.033)	(0.397)		(0.281)
g/s	9.314	0.890	8.25		6.15
(lb/h)	(73.927)	(7.066)	(65.477)		(48.825)
kg/Mg	0.153	0.0148	0.144		0.103
(lb/ton)	(0.305)	(0.0295)	(0.288)		(0.206)

TABLE A-17. SUMMARY OF UNCONTROLLED EMISSION TEST RESULTS--PLANT C--RAP MIX PROCESS UNIT: DRUM PLANT MIX

Data	Run No. R-1	Run No. R-2	Run No. R-3	Run No.	Average for test series
General					
Date	6/23/84	6/25/84	6/25/84		--
Sampling time, min	75	75	75		--
Isokinetic ratio, percent	102.3	102.6	101.4		--
Production rate, Mg/h (tons/h)	317 (349)	320 (353)	307 (338)		314 (346)
Gas stream data					
Temperature, °C (°F)	186.1 (367)	140 (284)	185.6 (366)		170.6 (339)
Moisture, percent	27.2	35.1	33.6		31.9
Flow rate, m^3/s (acfm)	32.25 (68,315.9)	30.92 (65,502.2)	32.20 (68,220.7)		31.79 (67,346.3)
Flow rate, dsm^3/s (dscfm)	14.98 (31,733)	14.12 (29,919)	13.56 (28,727)		14.22 (30,126.3)
Particulate emissions					
mg/dscm (gr/dscf)	12,673.65 (5.54)	16,020.50 (7.003)	15,594.99 (6.817)		14,763.05 (6.453)
g/s (lb/h)	189.97 (1,507.76)	226.27 (1,795.89)	211.50 (1,678.59)		209.25 (1,660.74)
kg/Mg (lb/ton)	2.16 (4.32)	2.544 (5.087)	2.48 (4.96)		2.39 (4.779)
Total Organic Carbon--TOC					
mg/dscm (gr/dscf)	25.164 (0.011)	146.41 (0.064)	93.79 (0.0410)		88.45 (0.0386)
g/s (lb/h)	0.3805 (3.02)	2.065 (16.39)	1.345 (10.068)		1.263 (9.83)
kg/Mg (lb/ton)	0.0043 (0.0086)	0.0232 (0.0464)	0.0149 (0.0297)		0.0142 (0.0284)

TABLE A-18. SUMMARY OF CONTROLLED EMISSION TEST RESULTS--PLANT C-- RAP MIX PROCESS UNIT: DRUM PLANT MIX

Data	Run No. R-1	Run No. R-2	Run No. R-3	Run No.	Average for test series
General					
Date	6/23/84	6/25/84	6/25/84		--
Sampling time, min	96	96	96		--
Isokinetic ratio, percent	93.6	102.5	100.1		--
Production rate, Mg/h (tons/h)	317 (349)	320 (353)	307 (338)		314 (346)
Gas stream data					
Temperature, °C (°F)	136.1 (277)	131.7 (269)	137.8 (280)		135 (275)
Moisture, percent	29.8	34.4	32.8		32.3
Flow rate, m³/s (acfm)	26.10 (55,296.6)	25.04 (53,055.2)	25.58 (54,195.6)		25.57 (54,182.5)
Flow rate, dsm³/s (dscfm)	13.21 (27,994)	11.87 (25,158)	12.25 (25,962)		12.45 (26,371.3)
Particulate emissions					
mg/dscm (gr/dscf)	41.17 (0.0180)	75.49 (0.033)	34.31 (0.015)		50.32 (0.022)
g/s (lb/h)	0.556 (4.417)	0.909 (7.215)	0.430 (3.410)		0.632 (5.014)
kg/Mg (lb/ton)	0.0063 (0.0126)	0.0102 (0.0204)	0.005 (0.0100)		0.0072 (0.0143)
Total Organic Carbon--TOC					
mg/dscm (gr/dscf)	34.315 (0.015)	146.41 (0.064)	173.86 (0.076)		118.18 (0.052)
g/s (lb/h)	0.466 (3.702)	1.73 (13.743)	2.123 (16.834)		1.44 (11.426)
kg/Mg (lb/ton)	0.0053 (0.0106)	0.0195 (0.0389)	0.0249 (0.0498)		0.0165 (0.0330)

TABLE A-19. SUMMARY OF VISIBLE EMISSIONS--PLANT C--CONVENTIONAL MIX

Date	7/25/84
Run No.	C-2[a]
Control device	Baghouse
Height of point of discharge, ft	40
Distance from observer to discharge point, ft	75
Direction of observer from discharge point	East
Description of background	Sky
Description of sky	Scattered clouds
Wind direction	Northeast
Wind velocity, mph	0-5
Color of plume	White; gray-white
Period of observation	0904-1301
Highest single reading, percent	25
Highest 6-minute average opacity, percent	12

[a] Data reading methods were inconsistent with Method 9 procedures.

TABLE A-20. SUMMARY OF VISIBLE EMISSIONS--PLANT C--CONVENTIONAL MIX

Date	7/25/84
Run No.	C-2[a]
Control device	Baghouse
Height of point of discharge, ft	40
Distance from observer to discharge point, ft	150
Direction of observer from discharge point	Southeast
Description of background	Sky
Description of sky	Cloudy
Wind direction	East
Wind velocity, mph	0-10
Color of plume	White; gray
Period of observation	1212-1251
Highest single reading, percent	25
Highest 6-minute average opacity, percent	15

[a] Readings intentionally taken 30 to 40 ft downwind from stack in an effort to measure blue haze that did not form at the stack.

TABLE A-21. SUMMARY OF VISIBLE EMISSIONS--PLANT C--CONVENTIONAL MIX

Date	7/25/84
Run No.	C-3[a]
Control device	Baghouse
Height of point of discharge, ft	40
Distance from observer to discharge point, ft	175
Direction of observer from discharge point	South, west
Description of background	Sky
Description of sky	Blue
Wind direction	South
Wind velocity, mph	0-25
Color of plume	White
Period of observation	1505-1636
Highest single reading, percent	60
Highest 6-minute average opacity, percent	44

[a] Data reading methods were inconsistent with Method 9 procedures.

TABLE A-22. SUMMARY OF VISIBLE EMISSIONS--PLANT C--CONVENTIONAL MIX

Date	7/26/84
Run No.	C-3[a,b]
Control device	Baghouse
Height of point of discharge, ft	40
Distance from observer to discharge point, ft	75
Direction of observer from discharge point	East
Description of background	Sky
Description of sky	Cloudy
Wind direction	West
Wind velocity, mph	0-15
Color of plume	White
Period of observation	0820-0835
Highest single reading, percent	0
Highest 6-minute average opacity, percent	0

[a] Continuation of Run C-3 which began on 7-25-84 (see Table A-21).

[b] Data reading methods are inconsistent with Method 9 procedures. Readings taken at end of plume, approximately 50 feet from stack.

TABLE A-23. SUMMARY OF VISIBLE EMISSIONS--PLANT C--CONVENTIONAL MIX

Date	7/26/84
Run No.	Particle size test[a]
Control device	Baghouse
Height of point of discharge, ft	40
Distance from observer to discharge point, ft	75
Direction of observer from discharge point	East
Description of background	Sky
Description of sky	Cloudy
Wind direction	North
Wind velocity, mph	0-15
Color of plume	White
Period of observation	0949-1047
Highest single reading, percent	40
Highest 6-minute average opacity, percent	32

[a] Data readings are inconsistent with Method 9 procedures. Readings taken at end of plume, approximately 60 ft from stack.

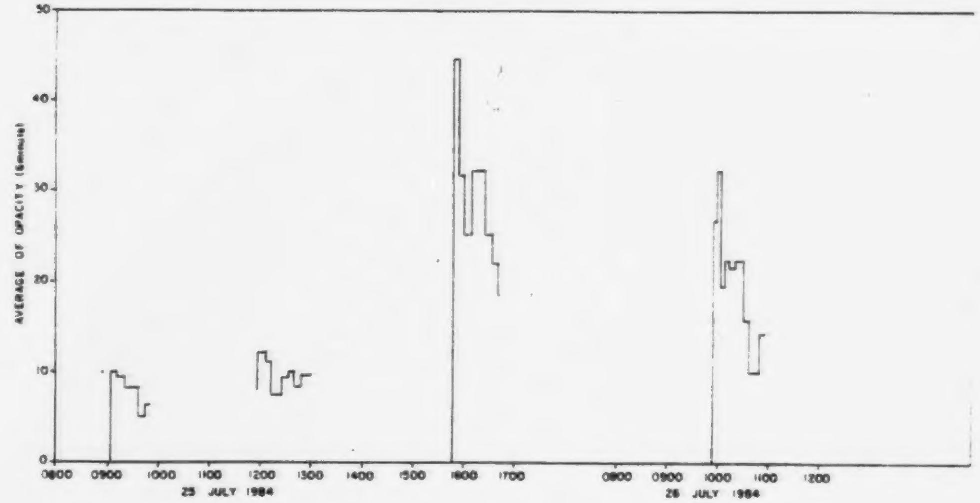


Figure A-8. Six-minute average opacity during conventional operation.

TABLE A-24. SUMMARY OF VISIBLE EMISSIONS--PLANT C--RAP MIX

Date	6/23/84
Run No.	R-1[a]
Control device	Baghouse
Height of point of discharge, ft	40
Distance from observer to discharge point, ft	200
Direction of observer from discharge point	East
Description of background	Sky
Description of sky	Hazy
Wind direction	North
Wind velocity, mph	10
Color of plume	White
Period of observation	0915-1036
Highest single reading, percent	35
Highest 6-minute average opacity, percent	25

[a] Data reading methods are inconsistent with Method 9 procedure. Readings taken approximately 20 ft from stack.

TABLE A-25. SUMMARY OF VISIBLE EMISSIONS--PLANT C--RAP MIX

Date	6/25/84
Run No.	R-2[a]
Control device	Baghouse
Height of point of discharge, ft	45
Distance from observer to discharge point, ft	100
Direction of observer from discharge point	East
Description of background	Sky
Description of sky	Blue
Wind direction	Northwest
Wind velocity, mph	10
Color of plume	White; light gray
Period of observation	1055-1353
Highest single reading, percent	25
Highest 6-minute average opacity, percent	9

[a] Data reading methods are inconsistent with Method 9 procedure. Readings taken approximately 10 ft from stack.

TABLE A-26. SUMMARY OF VISIBLE EMISSIONS--PLANT C--RAP MIX

Date	6/25/84
Run No.	R-3[a]
Control device	Baghouse
Height of point of discharge, ft	40
Distance from observer to discharge point, ft	120
Direction of observer from discharge point	Southwest
Description of background	Sky
Description of sky	Pale blue; hazy
Wind direction	South
Wind velocity, mph	5-20
Color of plume	White; gray
Period of observation	1523-1731
Highest single reading, percent	40
Highest 6-minute average opacity, percent	34

[a] Data reading methods are inconsistent with Method 9 procedure. Readings taken at 10 to 20 ft from stack.

TABLE A-27. SUMMARY OF VISIBLE EMISSIONS--PLANT C--RAP MIX

Date	6/25/84
Run No.	R-3[a]
Control device	Baghouse
Height of point of discharge, ft	40
Distance from observer to discharge point, ft	150
Direction of observer from discharge point	West
Description of background	Sky
Description of sky	Blue, hazy
Wind direction	South, southeast
Wind velocity, mph	10 to 15
Color of plume	White
Period of observation	1655-1731
Highest single reading, percent	35
Highest 6-minute average opacity, percent	26

[a] Readings taken intentionally 15 ft downwind from stack in an effort to measure blue haze which did not form at the stack.

Figure A-9. Six-minute average opacity during recycle operation.

TABLE A-28. SUMMARY OF UNCONTROLLED EMISSION TEST RESULTS--PLANT D--CONVENTIONAL MIX PROCESS UNITS: DRUM PLANT MIX

Data	Run No. C-1	Run No. C-2	Run No. C-3	Run No. C-4	Average for test series
General					
Date	9/24/83	9/25/83	9/26/83	9/27/83	--
Sampling time, min	72	48	48	48	--
Isokinetic ratio, percent	89.1	100.5	101.9[a]	99.8	--
Production rate, Mg/h (tons/h)	281 (310)	282 (311)	277 (305)	244 (269)	271 (299)
Gas stream data					
Temperature, °C (°F)	137 (279)	140 (284)	128 (263)	133 (271)	135 (274)
Moisture, percent	22.3	20.9	20.0	18.6	20.45
Flow rate, m^3/s (acfm)	17.63 (37,351.6)	19.74 (41,819.8)	19.72 (41,774.2)	18.80 (39,835.2)	18.97 (40,196.7)
Flow rate, dsm^3/s (dscfm)	9.74 (20,638)	11.17 (23,662)	11.7 (24,798)	11.15 (23,630)	10.9 (23,182)
Particulate emissions					
mg/dscm (gr/dscf)	105,982.82 (46.328)	257,728.04 (112.660)	200,939.11 (87.836)	122,389.94 (53.5)	171,759.98 (75,081)
g/s (lb/h)	1,032.596 (8,195.388)	2,878.913 (22,849.019)	2,325.539 (18,457.072)	1,365.289 (10,835.866)	1,900.58 (15,084.34)
kg/Mg (lb/ton)	13.218 (26.436)	38.235 (76.47)	30.255 (60.51)	20.14 (40.28)	25.225 (50.45)
Total Organic Carbon--TOC					
mg/dscm (gr/dscf)		105.23 (0.046)	38.89 (0.017)	96.08 (0.042)	80.06 (0.035)
g/s (lb/h)	a	1.1675 (9.266)	0.4672 (3.708)	1.076 (8.539)	0.903 (7.17)
kg/Mg (lb/ton)		0.0149 (0.0298)	0.0061 (0.0122)	0.01585 (0.0317)	0.0123 (0.0246)

[a] Contaminated sample.

TABLE A-29. SUMMARY OF CONTROLLED EMISSION TEST RESULTS--PLANT D-- CONVENTIONAL MIX PROCESS UNITS: DRUM PLANT MIX

Data	Run No. C-1	Run No. C-2	Run No. C-3	Run No. C-4	Average for test series
General					
Date	9/24/84	9/25/84	9/26/84	9/27/84	--
Sampling time, min	126	99	126	126	--
Isokinetic ratio, percent	98.7	101.1	101.2	97.9	--
Production rate, Mg/h	281	282	277	244	271
(tons/h)	(310)	(311)	(305)	(269)	(299)
Gas stream data					
Temperature, °C	124	123	120	123	123
(°F)	(256)	(253)	(248)	(253)	(253)
Moisture, percent	19	17.7	18	16.9	17.9
Flow rate, m^3/s	23.36	24.03	23.86	23.46	23.68
(acfm)	(49,488.5)	(50,904.1)	(50,555.8)	(49,709.6)	(50,164.4)
Flow rate, dsm^3/s	13.97	14.84	14.84	14.65	14.57
(dscfm)	(29,597)	(31,448)	(31,434)	(31,032)	(30,878)
Particulate emissions					
mg/dscm	18.301	57.192	64.054	50.328	47.469
(gr/dscf)	(0.008)	(0.025)	(0.028)	(0.022)	(0.0207)
g/s	0.2665	0.8643	0.9432	0.72083	0.698
(lb/h)	(2.115)	(0.016)	(7.498)	(5.721)	(5.545)
kg/Mg	0.0035	0.011	0.0125	0.0105	0.0095
(lb/ton)	(0.007)	(0.022)	(0.025)	(0.021)	(0.019)
Total Organic Carbon--TOC					
mg/dscm	41.18	41.18	36.60	36.60	38.89
(gr/dscf)	(0.018)	(0.018)	(0.016)	(0.016)	(0.017)
g/s	0.585	0.622	0.5362	0.524	0.567
(lb/h)	(4.643)	(4.937)	(4.256)	(4.159)	(4.499)
kg/Mg	0.0075	0.00795	0.007	0.0077	0.0076
(lb/ton)	(0.015)	(0.0159)	(0.014)	(0.0154)	(0.0151)

TABLE A-30. SUMMARY OF UNCONTROLLED EMISSION TEST RESULTS--PLANT D-- RAP MIX PROCESS UNIT: DRUM PLANT MIX

Data	Run No. R-1	Run No. R-2	Run No. R-3	Run No.	Average for test series
General					
Date	9/28/84	9/28/84	9/28/84		--
Sampling time, min	48	48	48		--
Isokinetic ratio, percent	103.5	104.6	106.7		--
Production rate, Mg/h (tons/h)	301 (332)	281 (310)	281 (310)		288 (317)
Gas stream data					
Temperature, °C (°F)	171 (340)	174 (346)	176 (349)		174 (345)
Moisture, percent	20.5	21.1	23.1		21.6
Flow rate, m^3/s (acfm)	206.31 (43,708.7)	199.84 (42,339.3)	205.09 (43,451.2)		203.745 (43,166.4)
Flow rate, dsm^3/s (dscfm)	109.95 (23,294)	104.99 (22,244)	104.85 (22,215)		106.598 (22,584)
Particulate emissions					
mg/dscm (gr/dscf)	16,208.08 (7.085)	25,013.3 (10.939)	19,799.72 (8.655)		20,340.367 (8.89)
g/s (lb/h)	178.238 (1,414.622)	262.78 (2,085.637)	207.734 (1,648.073)		216.251 (1,716.330)
kg/Mg (lb/ton)	2.13 (4.26)	3.364 (6.727)	2.659 (5.318)		2.707 (5.414)
Total Organic Carbon--TOC					
mg/dscm (gr/dscf)	64.05 0.028	164.7 0.105	56.57 0.035		88.94 0.056
g/s (lb/h)	0.7058 (5.602)	2.525 (20.046)	0.8502 (6.748)		1.36 (10.798)
kg/Mg (lb/ton)	0.008 (0.0168)	0.0323 (0.0646)	0.0105 (0.021)		0.017 (0.034)

TABLE A-31. SUMMARY OF CONTROLLED EMISSION TEST RESULTS--PLANT D-- RAP MIX PROCESS UNIT: DRUM PLANT MIX

Data	Run No. R-1	Run No. R-2	Run No.	Run No.	Average for test series
General					
Date	9/28/83	9/28/83			--
Sampling time, min	126	126			--
Isokinetic ratio, percent	106.8	105			--
Production rate, Mg/h (tons/h)	301 (332)	281 (310)			288 (317)
Gas stream data					
Temperature, °C (°F)	105.1 (302.2)	157.2 (315)			153.4 (308.6)
Moisture, percent	21.1	21.7			21.4
Flow rate, m³/s (acfm)	21.14 (44,969.2)	23.79 (50,615.1)			22.465 (47,792.15)
Flow rate, dsm³/s (dscfm)	11.79 (25,087)	12.96 (27,567)			12.375 (26,327)
Particulate emissions					
mg/dscm (gr/dscf)	18.301 (0.008)	13.726 (0.006)			16.014 (0.007)
g/s (lb/h)	0.2109 (1.674)	0.1868 (1.483)			0.198 (1.578)
kg/Mg (lb/ton)	0.0025 (0.005)	0.0024 (0.0048)			0.0025 (0.0049)
Total Organic Carbon--TOC					
mg/dscm (gr/dscf)	137.26 (0.06)	116.67 (0.51)			125.82 (0.055)
g/s (lb/h)	1.625 (12.889)	1.159 (12.059)			1.57 (12.479)
kg/Mg (lb/ton)	0.0194 (0.0388)	0.01945 (0.0389)			0.01965 (0.0393)

TABLE A-32. SUMMARY OF VISIBLE EMISSIONS--PLANT D--CONVENTIONAL MIX

Date	9/25/84
Run No.	C-2
Control device	Baghouse
Height of point of discharge, ft	25
Distance from observer to discharge point, ft	50
Direction of observer from discharge point	South
Description of background	Sky
Description of sky	Blue
Wind direction	Northwest
Wind velocity, mph	15
Color of plume	White/gray
Period of observation	1300-1736
Highest single reading, percent	5
Highest 6-minute average opacity, percent	1.25

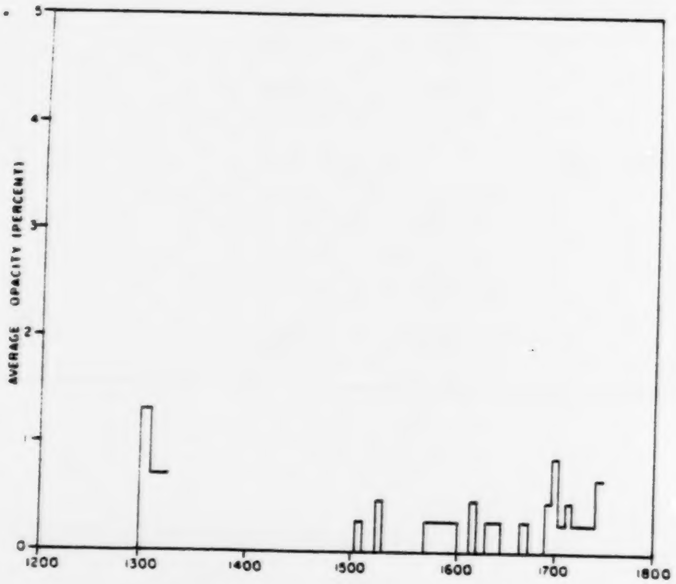


Figure A-10. Six-minute average opacity during conventional operation.

TABLE A-33. SUMMARY OF VISIBLE EMISSIONS--PLANT D--RAP MIX

Date	9/28/84
Run No.	R-1
Control device	Baghouse
Height of point of discharge, ft	25
Distance from observer to discharge point, ft	50
Direction of observer from discharge point	South
Description of background	Sky
Description of sky	Blue
Wind direction	North northwest
Wind velocity, mph	10
Color of plume	White/gray
Period of observation	1032-1457
Highest single reading, percent	5
Highest 6-minute average opacity, percent	5.0

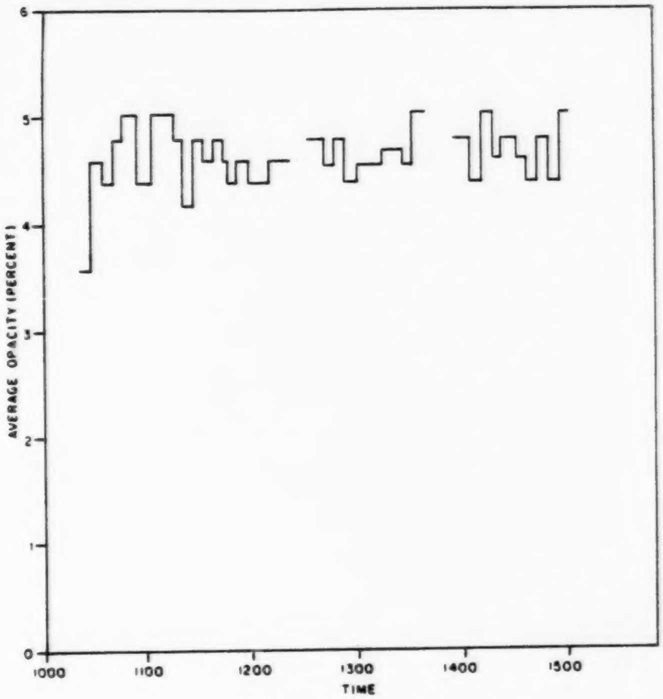


Figure A-11. Graphic representation of visual emission observations.

APPENDIX B

SUMMARY OF STATE REGULATIONS FOR ASPHALT CONCRETE FACILITIES

A review of State regulations for asphalt concrete plants indicates that most States have adopted the same emission limits as required by the present NSPS for this industry. Those States that presently have standards more stringent than the current NSPS are listed in Table B-1. Reference Method 5, established by the EPA, is used by all of these States except Pennsylvania, which includes the soluble portions of the back-half catch in its results.

TABLE B-1. STATES WITH AIR EMISSION STANDARDS FOR ASPHALT CONCRETE PLANTS STRICTER THAN THE NSPS OF 90 mg/dscm (0.04 gr/dscf)

State	Standard		
	mg/dscm	gr/dscf	
New Jersey[1]	45.8	0.02	If generate ≧50 lb/h particulate. Ninety-nine percent collection efficiency (or 0.5 lb/h) if generate <50 lb/h particulate.
New York[2]	68.8	0.03	For plants that operate above 250,000 pounds per hour.
Pennsylvania[3]	45.8	0.02	Unless the following formula yields a more lenient standard: $A = 0.76\ E^{0.42}$, where E = F X W (F = 6 lb/ton aggregate feed) W = tons/h (aggregate feed) A = lb/h
Utah[4]	45.8	0.02	Plants producing virgin mix.
	80.3	0.035	Plants producing recycle mix.
D.C.[5]	68.8	0.03	Zero percent opacity.
Maryland[6]	68.8	0.03	

REFERENCES FOR APPENDIX B

1. Telecon. M. Maul, MRI, with D. Blasi, and L. Mikolajczyk, New Jersey Bureau of Air Pollution Control. January 17, 1984. State regulation.
2. Telecon. M. Maul, MRI, with D. Spencer, and B. Kerr, New York Department of Environmental Conservation. January 17. 1984. State regulation.
3. Telecon. M. Maul, MRI, with J. Benson, Pennsylvania Department of Environmental Regulation. January 17, 1984. State regulation.
4. Telecon. M. Maul, MRI, with M. Keller, Utah Bureau of Air Quality. January 30, 1984. State regulation.
5. Telecon. M. Maul, MRI, with D. Wambsgans, District of Columbia Department of Environmental Services. January 20, 1984. District regulation.
6. Telecon. B. Terry, MRI, with K. Gunkel, Maryland Air Management Administration. January 17, 1984. State regulation.

APPENDIX C
EMISSION MEASUREMENT METHODS

C.1 INTRODUCTION

C.1.1 Background

The EPA Office of Air Quality Planning and Standards conducted an emission test program at four asphalt concrete producing facilities between November 1983 and September 1984. Selection of the test sites was based upon (1) processing of recycled asphalt pavement (RAP), (2) type of operation and/or emissions control systems, (3) results obtained during prior NSPS compliance testing, and (4) suitability for isokinetic testing.

The test program consisted of sampling conventional and recycled asphalt concrete process emissions at uncontrolled and controlled sources. The emission control devices consisted of two baghouses and two scrubber systems.

C.1.2 Objective

The purpose of the emission test program was to determine and evaluate emission levels being generated from asphalt concrete plants producing conventional and RAP mixes. The test program included determining emission levels for the following parameters:

1. Particulate matter;
2. Total organic carbon/extractable organics;
3. Visible emissions;
4. Particle size;
5. Polynuclear aromatic hydrocarbons;
6. Scrubber and baghouse process samples; and
7. Trace metal emissions.

The following narrative describes the rational for selection of the methods used, the sampling procedures and equipment configurations, the sample recovery procedures, and the analytical procedures used to obtain the test data.

C.2 SELECTION OF SAMPLING AND ANALYTICAL METHODS

C.2.1 Preliminary Review

The EPA investigated several candidate sampling and analytical procedures for measuring emissions from the asphalt concrete process. The major pollutants of interest were particulate matter and condensible hydrocarbons. The investigation consisted of reviewing test methods that had previously been used to sample and analyze asphalt concrete plant particulate emissions. Currently, EPA Method 5 is specified for NSPS compliance testing. In addition, several procedures to determine levels of condensible hydrocarbons and their relationship to blue haze were evaluated.

The conclusion reached from the preliminary review for the particulate emissions testing was that EPA Method 5 would be the best method. The Method 5 procedure would allow the collected information (front half catch) to be compared with the data collected previously during NSPS compliance testing.

Three condensible hydrocarbon methods were selected for preliminary screening. Method 25, which produces a total carbon number, was rejected because of the overriding interferences of carbon dioxide and water in the emission sources. Extractable organics as determined from the ether/chloroform extract of the 0.1 N NaOH impinger solution and gravimetric analysis was the second condensible hydrocarbon method rejected from consideration. The extracted organic method was eliminated because of a loss of organic hydrocarbons that was encountered during analytical operations. Reference Method 5E, which determines total organic carbon (TOC) content by subtracting the total inorganic carbon from the total carbon content, was selected. The use of this method provided the following conveniences for the test program:

1. The sample collection train could be combined with the Method 5 configuration, thereby allowing particulate and condensible hydrocarbon results to be determined simultaneously;

2. The TOC number could be converted to a weight basis by using the molecular weight of carbon, thus allowing the results to be added to the particulate emissions, if desired;

3. The Method 5E (TOC) had been tried and proven in a standards development testing program (wool fiberglass manufacturing);

4. Method 5E is simple and relatively easy to perform; and

5. Method 5E could be used to determine the uncontrolled and controlled emission levels without any modification of detection limits or sampling and analytical procedures.

Reference Method 9 protocol was selected for evaluating the visible emissions. Because of the different control devices (baghouses and scrubbers), the color of the plume (blue/gray haze), and the temperature-dependent opacity, specific observation procedures had to be considered for each test site.

Particle size determination test procedures were evaluated prior to the emission test program. Because of the high moisture (30 percent), excessive grain loading (75.0 grains/dscf), and temperature (350°F) encountered at the inlet to the control devices, an Andersen High Capacity Stack Sampler was selected to determine the uncontrolled particle size distribution. This unit allowed a reasonable sampling time to be performed at isokinetic sampling conditions. The controlled emission sources required a different unit because of the fairly low grain loading (0.03 grains/dscf) and the saturated gas stream associated with the scrubber control devices. An Andersen Mark III with a precutter separator and nine fraction sizes was selected for the controlled emission sources. The precutter was specified to limit the quantity of large particles being drawn into the impactor.

Polynuclear aromatic hydrocarbon (PAH) test procedures were evaluated prior to the emission test program. Sampling, sample recovery, and sample analysis protocols were selected from state-of-the-art established procedures. Major organic species and benzo(a)pyrene were selected to be analyzed by gas chromatography-mass spectrometry (GC-MS) for four field samples. The major organic species analyzed were selected based upon relative peak heights of the GS-MS scan.

Sampling and/or monitoring of control devices and process operations was conducted according to procedures established prior to the sampling program. Analytical methods were selected for evaluating the individual process samples and are described in the following:

Sample type	Analysis	Analytical method
Virgin aggregate	Percent moisture	Modified ASTM
RAP	Percent moisture	Modified ASTM
RAP	Smoke point	Oklahoma Test Lab
RAP	Flash point	Oklahoma Test Lab
Asphalt cement	Smoke point	ASTM D92
Asphalt cement	Flash point	ASTM D92
Scrubber water	Dissolved solids	ASTM
Scrubber water	Suspended solids	ASTM
Scrubber water	TOC	EPA Method 5E
Scrubber water	pH	Instrument
Scrubber water	Temperature	Instrument
Scrubber water	Trace metals	ICAPES
Scrubber water	PAH	GS-MS

Trace metal test procedures were evaluated prior to the emission test program. Two analytical procedures were considered for the trace metals; atomic absorption spectroscopy (AAS) and inductively-coupled argon plasma emission spectroscopy (ICAPES). The ICAPES technique was selected over the AAS procedure primarily because of lower cost and less time required to analyze the large number of samples. Although the AAS technique is more sensitive and has a lower detection limit, it requires that each element be determined by a separate analysis. The ICAPES system is computer-controlled, which allows for simultaneous multi-element determinations. The AAS unit is believed to be more accurate; however, the ICAPES system provides for an automatic background correction to adjust for matrix interferences. Thirteen elements were selected for trace metal investigation.

C.2.2 Preliminary Field Evaluation and Analysis

An actual preliminary field evaluation of the selected methods was not conducted prior to the standard development program. However, a number of sampling and analytical protocols were performed and compared during the NSPS field test program. The following describes these different variations.

C.2.2.1 Sampling. The impinger train configuration and impinger contents varied depending upon the emission specie(s) of interest. Additional impingers were added during several runs to collect trace metal samples. Extra impingers were inserted when high moisture levels (35 percent) were experienced in the gas stream.

The fiberglass filter temperature was controlled automatically by a time proportioning temperature controller using a thermocouple positioned in the exit stream of the glass filter holder. The exit stream of the filter was to be maintained at 250°F ± 10°F.

A stainless steel probe was used during several runs at the plant A outlet location. High winds and stack vibrations had broken all of the glass liner probes that the contractor had available.

C.2.2.2 Sample Recovery. No water rinse was performed on the probe as is specified in the Method 5E procedures. It was not necessary to separate water soluble particles from the remaining particulate catch.

The acetone rinse of the probe was followed by a second organic solvent rinse using trichloroethane at test site A. Particulate removal efficiency of the acetone was being evaluated. The rinses were stored and analyzed separately.

A trichloroethane rinse that is not specified in Method 5E was performed on the impingers following the 0.1 N NaOH rinse. A thin black film adhered to the impinger walls and could be removed only with an organic solvent.

C.2.2.3 Sample Analysis. Condensible hydrocarbons were analyzed by two different methods for test site A to evaluate and compare the results of the two analytical procedures. The TOC was determined by EPA Method 5E, and extractable organics were determined by the ether/chloroform extraction, evaporation, and drying procedures.

The Method 5E TOC samples were analyzed by two different techniques. Samples from site A (inlet and outlet) were analyzed, first, by acidifying the sample below a pH of 2 with H_2SO_4 and purging with nitrogen to remove the inorganic carbon. The second method was performed according to EPA Method 5E protocol (analyzing total inorganic carbon and total carbon and determining organic carbon by difference). A series of analyses using these two methods was performed during a 4-month period (see Appendix B).

Impinger contents were recovered and analyzed separately for two of the test sites. Each impinger was recovered and analyzed separately for TOC content to determine the collection efficiency of the train configuration.

The black film rinse recovered from the impingers was reduced by drying and then weighed to determining the organic mass.

C.3 SAMPLING AND ANALYSIS TEST PROGRAM

C.3.1 Particulate Emissions Testing

Particulate emission tests were performed in accordance with EPA Reference Method 5 (40 CFR Part 60-Appendix A) for the standards development portion of the testing. Multiple point isokinetic sampling was conducted at sampling points located according to EPA Methods 1 and 2 wherever the site permitted. Sampling was conducted in locations as close as possible to the specified points.

Entrained water droplets were encountered at the two scrubber outlet locations. Despite the water droplets and the proximity of some sampling locations to flow disturbances, the test results are considered to be representative of the source emissions. Testing was conducted on uncontrolled and controlled process emissions during production of both conventional and recycle mixes. Sample recovery and particulate analytical determinations were performed in accordance with criteria presented in the reference method.

C.3.2 Visible Emissions Testing

Visible emission measurements of the control source effluent were conducted in accordance with EPA Reference Method 9 (40 CFR Part 60-Appendix A). Observations of visible emissions from a single controlled source (scrubber, baghouse discharge) to the atmosphere were performed concurrent with the emissions sampling when appropriate. Opacity readings were recorded every 15 seconds and summarized in 6-minute averages. Observations were performed during production of both conventional and recycle mixes except during interruption in production or testing or when a contrasting background for the blue/gray plume was unavailable. Each observer location was selected to provide both a clear view of the effluent emissions without interference from the sun or overcast sky and a line of vision approximately perpendicular to the plume direction with a contrasting background.

The two scrubber visible steam plumes were attached to the stack; consequently, readings were performed beyond the point in the plume where the condensed water vapor was no longer visible. The effluent emissions from the two baghouses were observed immediately above the stack exit as condensed moisture did not interfere with the opacity measurements at this point.

Visible emissions values obtained under these two different conditions should not be compared because of the varying plume density, plume diameter, potential emission condensation, and residual condensed moisture interferences. When observations are performed after the disappearance of the scrubber steam plume, the remaining plume normally is lightened by dispersion. In contrast, the blue haze often observed with the production of recycle mixes appears to darken as the emissions cool and drift away from the stack. Because of these interferences, opacity readings on the scrubber exhaust effluent are not good indicators of the emission levels or the performance of the scrubber device.

The remaining tests that were conducted for secondary information for the test program do not affect the standard development results and, therefore, are not discussed in this document.

C.4 MONITORING SYSTEMS

C.4.1 Continuous Opacity Monitoring

Many new source performance standards for particulate emissions require transmissometers (opacity monitors) to ensure proper operation and maintenance of control devices. Transmissometer measurements are not necessarily representative of opacity or mass emissions for the effluent streams generated from asphalt concrete plants and, therefore, are not recommended for this source. It is possible, for transmissometers to be operated on baghouse sources if the ambient temperature is above the dew point of the stack gas.

The visible particulate matter can vary with the stack gas temperature, thus eliminating any correlation of the transmissometer measurements with EPA Method 9 results. For example, at elevated stack temperatures, condensible particulate emissions may exist in a vapor state and would not be detected by the transmissometer. These emissions would later recondense and be visible in the atmosphere.

Reference Method 9 is recommended on a daily basis for monitoring the operation and maintenance of the process control devices. When condensed moisture is present in the effluent stream such as from wet scrubbers, Method 9 is not applicable, and another monitoring parameter should be considered. Easily measured process parameters such as the scrubber unit pressure drop and/or scrubber liquid flow rate should be considered in lieu of continuous opacity monitors and Method 9 in these cases.

C.4.2 Pressure Drop and Scrubber Liquid Flow Rate Continuous Monitoring

When scrubber systems are used for asphalt concrete plant emission control, effluent gas pressure drop and scrubber liquid flow rate measuring devices are recommended for monitoring the operation. Calibration and maintenance intervals of the measuring unit should be established according to manufacturer specifications.

The initial equipment and installation cost for installing a pressure drop measurement device, a scrubber liquid flow rate meter, and associated automatic monitoring equipment is estimated to be less than $3,000 per site. Annual operating cost including maintenance and data filing would be approximately $750/site.

C.5 PERFORMANCE TEST METHODS

C.5.1 Particulate Emissions

Consistent with prior testing and with the data base gathered during the standards development test program, the recommended performance test method for particulate matter is EPA Method 5 (40 CFR Part 60-Appendix A).

Sampling cost for a performance test consisting of these Method 5 runs is estimated to be between $6,000 and $9,000. If plant personnel are used to conduct the test, the cost would be less.

C.5.2 Visible Emissions

Reference Method 9 (40 CFR Part 60-Appendix A) is the performance test method recommended for measurement of opacity for the asphalt concrete plant exhaust sources. Method 9 is recommended for all sources except exhaust sources where condensible particulate and/or hydrocarbon matter may be combined with moisture or water droplets to cause an interference with opacity determination.

TECHNICAL REPORT DATA

(Please read Instructions on the reverse before completing)

1. REPORT NO. EPA 450/3-85-024	2.	3. RECIPIENT'S ACCESSION NO.
4. TITLE AND SUBTITLE Second Review of New Source Performance Standards for Asphalt Concrete Plants		5. REPORT DATE October 1985
		6. PERFORMING ORGANIZATION CODE
7. AUTHOR(S)		8. PERFORMING ORGANIZATION REPORT NO.
9. PERFORMING ORGANIZATION NAME AND ADDRESS Office of Air Quality Planning and Standards U.S. Environmental Protection Agency Research Triangle Park, NC 27711		10. PROGRAM ELEMENT NO.
		11. CONTRACT/GRANT NO.
12. SPONSORING AGENCY NAME AND ADDRESS DAA for Air Quality Planning and Standards Office of Air and Radiation U.S. Environmental Protection Agency Research Triangle Park, NC 27711		13. TYPE OF REPORT AND PERIOD COVERED
		14. SPONSORING AGENCY CODE EPA 200/04

15. SUPPLEMENTARY NOTES

16. ABSTRACT

This report reviews the current New Source Performance Standards for Asphalt Concrete Plants. It includes a summary of the current standards, the status of current applicable control technology, and the ability of plants to meet the current standards.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
Air Pollution Asphalt Concrete Plants Hot Mix Asphalt Facilities Particulate Matter Standards of Performance Pollution Control	Air Pollution	13B

18. DISTRIBUTION STATEMENT Unlimited	19. SECURITY CLASS *(This Report)* Unclassified	21. NO. OF PAGES 147
	20. SECURITY CLASS *(This page)* Unclassified	22. PRICE

EPA Form 2220-1 (Rev. 4-77) PREVIOUS EDITION IS OBSOLETE